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A Preliminary Summary of
Progress and Plans

AUG 12 1964

C & R-PREP.

CITRUS AND SUBTROPICAL FRUIT RESEARCH

of the United States Department of Agriculture
and
in cooperation with
State Agricultural Experiment Stations

Prepared for the Department's
CITRUS AND SUBTROPICAL FRUIT RESEARCH AND MARKETING ADVISORY COMMITTEE
for its 17th Annual Meeting
Orlando, Florida
November 17-23, 1960

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This progress report is primarily a tool for use by advisory committee members in developing recommendations for present and future research programs and by USDA administrators for developing, coordinating, and evaluating research plans. Included in it are summaries of research done during the past year. Some are tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to advisory committee members, research administrators, and others having special interest in the development of public agricultural research programs.

The report also lists publications of research results issued during the year. Current agricultural research findings are also reported in the monthly USDA publications, "Agricultural Research" and "Agricultural Marketing."

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UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.

FUNCTIONS OF ADVISORY COMMITTEES

The Citrus and Subtropical Fruit Advisory Committee is one of twenty-four commodity and functional committees of the U. S. Department of Agriculture established pursuant to Title III of the Research and Marketing Act of 1946. Functions of the members of these committees include:

1. Acquainting themselves with the problems of producers, processors, distributors, and consumers, and presenting them for committee consideration.
2. Reviewing the current research and marketing service programs of the Department and recommending adjustments, including terminations, in the current program in order that available funds, personnel, and facilities will be used on problems of greatest importance.
3. Recommending new work or expansion of current work and indicating relative priority of such recommendations, when the current program is insufficient to develop solutions for important problems.
4. Developing a better understanding of the nature and value of the agricultural research program, explaining it to interested groups and organizations and encouraging the wider and more rapid applications of the findings of research.

The committees perform an important function in advising with respect to the development of the Department's research and marketing service programs. However, committee members recognize that the development of budgets and the implementation and administration of research and marketing programs are responsibilities of the Department.

A progress report similar to this one is prepared for each committee. The areas of the other twenty-three committees are:

Cotton and Cottonseed	Oilseeds and Peanut
Dairy	Potato
Deciduous Fruit and Tree Nut	Poultry
Economics	Refrigerated and Frozen Products
Farm Equipment and Structures	Rice
Food and Nutrition	Sheep and Wool
Food Distribution	Soils, Water and Fertilizer
Forage, Feed and Seed	Sugar
Forestry	Tobacco
Grain	Transportation
Home Economics	Vegetable
Livestock	

This progress report was compiled by Roy Magruder, Executive Secretary, Citrus and Subtropical Fruit Research and Marketing Advisory Committee, Office of the Administrator, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

CODES TO DESIGNATE UNITS CONDUCTING RESEARCH

AGRICULTURAL RESEARCH SERVICE (ARS)

Farm Research Divisions

AE	. . . . .	Agricultural Engineering
ADP	. . . . .	Animal Disease and Parasite
AH	. . . . .	Animal Husbandry
CR	. . . . .	Crops
ENT	. . . . .	Entomology
FE	. . . . .	Farm Economics
SWC	. . . . .	Soil and Water Conservation

Utilization Research and Development Divisions

EU	. . . . .	Eastern
NU	. . . . .	Northern
SU	. . . . .	Southern
WU	. . . . .	Western

Home Economics Research Divisions

CH	. . . . .	Clothing and Housing
HHE	. . . . .	Household Economics
HN	. . . . .	Human Nutrition

AGRICULTURAL MARKETING SERVICE (AMS)

Economics Statistics Divisions

AEC	. . . . .	Agricultural Economics
AES	. . . . .	Agricultural Estimates

Marketing Research Divisions

MD	. . . . .	Market Development
ME	. . . . .	Marketing Economics
MQ	Market Quality
TF	Transportation and Facilities

FCS	FARMER COOPERATIVE SERVICE
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FAS	FOREIGN AGRICULTURAL SERVICE
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FOREST SERVICE (FS)

Forest Research Divisions

FDR	Forest Diseases
FER	Forest Economics
FFR	. . . . .	Forest Fire
FIR	. . . . .	Forest Insect
FMR	. . . . .	Forest Management
FPR	Forest Products Utilization
RMR	Range Management and Wildlife Habitat
WMR	Watershed Management

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I. FARM RESEARCH

A. Breeding and Genetics

1. PLANT INTRODUCTION AND DEVELOPMENT

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Problem: Both foreign and domestic citrus varieties and strains of promise need to be introduced into citrus-growing regions where they do not now occur for possible use in commercial production or in breeding.

Program: A continuing program involving combing the literature from other countries and in some cases sending plant specialists to those countries to study and collect material of possible value (plant material is brought in both as budwood and as seed). In the United States budwood material, after quarantine and evaluation at Federal Plant Introduction Stations at Glendale, Maryland; Miami, Florida; and Riverside, California is sent to Federal and State research workers interested in it. The budwood sent to the University of California is virus indexed and later distributed to Federal and State research workers interested in it. Seeds brought in from foreign countries are sent to Federal and State research workers where they are grown as seedlings to obtain lines of those varieties which in most instances are virus free and may be nucellar. Budwood of seedling lines and of some indexed old-line material is exchanged among the domestic areas of the Rio Grande Valley of Texas, the Salt River Valley of Arizona, and those parts of California not under California quarantine against tristeza and other viruses. Between two and three Federal professional man years is expended on this work.

Progress: The following 84 introductions of citrus and related genera were made during the year:

<u>Species</u>	<u>Number of Introductions</u>	<u>Source</u>
Chaetospermum glutinosum	1	Bel. Congo
Citropsis gabunensis	1	Bel. Congo
Citropsis gillettiana	1	Bel. Congo
Citropsis latialata	1	Bel. Congo
Citrus aurantifolia	5	Ivory Coast
	1	New Guinea
	4	Morocco
Citrus aurantium	1	Ivory Coast
Citrus depressa	1	Japan
Citrus grandis	1	Cuba
	3	French Guinea
	1	Morocco

<u>Species</u>	(cont.)	<u>Number of Introductions</u>	<u>Source</u>
Citrus grandis		1	Tahiti
		1	Taiwan
Citrus hystrix		1	Morocco
Citrus limon		1	Bel. Congo
		1	French Guinea
Citrus medica		2	French Guinea
		1	Mexico
		3	Morocco
Citrus reticulata		2	Bel. Congo
		1	Ivory Coast
		3	Malaya
		4	Morocco
		2	Tahiti
Citrus sinensis		6	Bel. Congo
		1	Ivory Coast
		8	Japan
		8	Morocco
		2	Tahiti
Citrus spp. (Undetermined)		1	French Guinea
		1	India
		2	Japan
		1	Madagascar
		3	Malaya
		2	Morocco
		1	New Guinea
		1	Thailand
Clymenia polyandra		1	New Guinea
Eremocitrus glauca		1	Australia
Feronia limonia		1	Bel. Congo
Microcitrus warburgiana		1	New Guinea

Most of the above introductions were secured as seed and, after treatment, were sent into all States where citrus is grown. Many of these introductions were made by Dr. Harry W. Ford of the Florida Agricultural Experiment Station at Lake Alfred, whose collecting trip to the Belgian Congo was sponsored by the Florida Citrus Mutual. The primary objective of this exploration was to collect additional material of the *Citropsis gillettiana* for the burrowing nematode screening program. Additional collections of citrus and citrus relatives were received as a result of exploration trip to Southeastern Asia by H. Kamemoto and R. A. Hamilton of the Hawaii Agricultural Experiment Station.

Budwood of 19 citrus introductions was sent to the Citrus Experiment Station of California for virus indexing. This brings the total to 122 introductions of citrus and related genera which have been sent to Riverside, California, in 8 shipments since the program started in November 1954.

During the year budwood of 9 varieties was received at Indio, California, from Weslaco, Texas, and Orlando, Florida, and seed of 34 foreign varieties was received at Indio through the Federal Plant Introduction Stations.

Also during the year budwood of 49 new hybrids from Indio, California and Orlando, Florida was received at Weslaco, Texas. During the year permission was obtained from the Florida Plant Board for the introduction into Florida of budwood of seedlings of 4 new hybrids from Indio for use in the breeding work.

Seedlings of 30 commercial varieties of oranges and lemons from Italy and Spain introduced in California in 1955 and seedlings of 25 of the best Orlando mandarin hybrids introduced in California in 1956 have nearly reached bearing age at the U. S. Date Garden at Indio, California.

The cooperative program with the University of California at Riverside to screen the avocado collection maintained at the U. S. Plant Introduction Station at Miami, Florida for resistance of *Phytophthora cinnamomi* has been in operation for one year. To date 117 seedlings representing 18 introductions have been tested. One introduction -- Cellon's Hawaii -- has shown better than average resistance.

Additional introductions of the Chinese Gooseberry, *Actinidia chinensis*, received during the year from New Zealand, are being propagated for evaluation at the U. S. Plant Introduction Station at Chico, California. Other introductions received during the year include 5 mango and one avocado varieties.

Plans: Exploration by the New Crops Branch for additional citrus and subtropical fruit will be undertaken upon recommendation from the Advisory Committees or related research agencies and in accordance with priority needs of other crop groups. The U. S. Date Field Station at Indio, California and the U. S. Fruit, Vegetable, Soil & Water Research Laboratory at Weslaco, Texas will continue to grow and test foreign and domestic introductions that show promise of usefulness for commercial production or for breeding. The U. S. Horticultural Station at Orlando, Florida will continue its efforts to introduce citrus material that shows promise for citrus breeding work.

Publications: Some Fruits and Nuts for the Tropics. W. C. Kennard and H. F. Winters. U. S. Dept. Agr. ARS Misc. Pub. No. 801, 135 pp., illus. 1960.

2. BREEDING AND VARIETY EVALUATION

Problem: New citrus fruits suited to Florida, the Rio Grande Valley of Texas, and the hot desert areas of California and Arizona are needed. These include a series of loose-skinned fruit of good quality and appearance, an early sweet orange of good quality and size, a cold-hardy lemon, an early-maturing grapefruit and a late red grapefruit of attractive color. New date varieties better suited to the climatic conditions of the American date-growing areas are needed.

Program: This continuing citrus breeding program is being conducted on a regional basis at Indio and Brawley, El Centro, and Riverside, California; Weslaco, Texas; and Orlando, Florida in cooperation with the State Agricultural Experiment Stations; Brock Ranches, El Centro, California; Rio Farms, Inc., Edcouch, Texas; and the Florida Citrus Research Foundation. The crosses are made at Indio and Orlando and the seedlings are grown to fruiting and evaluated at Indio, Brawley and El Centro, California; at Edcouch, Texas; and at Orlando and Leesburg, Florida. The date breeding program is conducted at Indio and Brawley, California. The work involves 3 Federal professional man years.

Progress: Citrus breeding in California. Twenty-seven seedlings, representing various combinations between tangerines, tangelos, Temple orange and satsuma, 1 red grapefruit x shaddock hybrid, and 1 lemon hybrid were selected in 1960 from the Brawley plantings for second trial on standard stocks. The 1960 selections were propagated for second test at Indio and budwood was sent to Weslaco, Texas; to Brock Ranches, El Centro, California; and to the Citrus Experiment Station, Riverside, California, for propagation for testing.

About 6,000 seedlings grown at Indio from the 1959 crosses were sent to Brock Ranches, East Mesa Ranch, for field planting May 1960, and about 6,000 seed from the 1959 crosses were sent to Weslaco, Texas for planting.

Brock Ranches planted at the East Mesa Ranch about 90 selections from the Indio and Brawley plantings made during the past 5 years. Ten trees of each selection were propagated on Rough lemon and 2 of each on Troyer rootstock.

In 1960, extensive work was done in trying to produce crosses between Minneola as seed parent and grapefruit and tangelo varieties. Crosses of Wilking tangerine x tangerines and tangelos, of shaddocks x grapefruit, and Temple x tangelos and tangerines were made. Fruit set was poor, so that very large numbers of seeds are not expected from these crosses.

In the backcrossing program pursued with dates to produce males suitable for crossing varieties, the seeds from the first backcrosses have been obtained in 29 lines and from second backcrosses in 11 lines.

Land for citrus breeding in California. Negotiations are under way for the transfer of a 80-acre tract of land near Indio, California, from the Bureau of Reclamation, Dept. of Interior, to Crops Research, A.R.S., U.S.D.A.

While negotiations are under way for this land which would be valuable for fruiting out hybrids in the Indio area, additional land has been obtained on a cooperative basis from the Brock Ranches on the East Mesa, El Centro, California. During the past year 11,040 budded trees of 95 of the Indio citrus hybrid selections were planted on the Brock Ranches, occupying about 15 acres. Also, 6,000 F-1 citrus hybrids were planted as seedlings in a 10-acre block on the Brock Ranches. Plans are to plant 6,000 more seedlings during the coming year. The Brock Ranches also have made an extensive planting of different date varieties from the Indio Date Field Station. These plantings were made with Brock Ranches under the standard Memorandum of Understanding for testing fruit seedlings. The Brock Ranches pay all expenses of care after the U.S.D.A. delivers the trees or seedlings for planting. The U.S.D.A. research workers have free access to examine the hybrids as they fruit and the right to cut budwood. The U.S.D.A. has control of the hybrids until they are named and released or until they are marked for discard and destruction.

Citrus breeding in Florida. In 1960 abnormally cold and often rainy weather retarded blooming in many varieties while others were less affected by the adverse weather. This extended the breeding season from mid-February to approximately April 10, when sudden hot weather finally brought the blooming period to its ultimate peak and rapid termination within a few days. Twelve types of crosses were made that were designed to produce early-maturing round oranges with high solids and rich colored juice, early grapefruit of high quality, and early-maturing high-quality mandarins without the disadvantage of seediness that is characteristics of our present F-1 mandarin hybrids. Twenty-two varieties of sweet oranges were crossed to male parents that would contribute dominant, easily-recognized characteristics to the hybrid progeny so that nucellar seedlings could be selected with certainty for the establishment of new virus-free nucellar lines of these 22 old-line varieties for planting at the new Florida Citrus Research Foundation Farm near Leesburg. Budwood of Robinson, Osceola and Lee, the three new tangerine hybrids, was released and distributed to the Florida Citrus Nurserymen who applied for it.

The Florida Citrus Research Foundation Farm. Progress has been made in the development of the land recently acquired from the Florida Citrus Research Foundation. Seventy acres of land has been cleared and 40 acres specially prepared for a nursery. Six thousand seedlings grown in flats of sterilized soil at Orlando have been planted in the nursery. Older seedlings that had been previously planted in old nursery sites at the Phillips Tract near Orlando will not be transplanted to the new land for fear of transmitting nematodes and other undesirable soil-borne organisms. These older seedlings will only be transferred as budwood after it has been determined that they are tristeza-free. Six thousand Key lime seedlings are now ready in screened greenhouses at Orlando for testing purposes, and 6,000 Pusk citrange seedlings are growing at the Foundation farm for rootstocks.

Citrus pollen storage studies in Florida. A study on citrus pollen storage and subsequent germination in an artificial environment was also initiated in Florida in 1960. Laboratory testing indicated that 10° F. storage was superior to 40° F. storage for Poncirus trifoliata pollen. The opposite was true for Orlando tangelo pollen. Responses did not differ appreciably for Rough lemon, Carrizo, or Pineapple after several months of storage. Present indications are that P. trifoliata can be successfully stored at 10° F. for a year.

Citrus breeding and variety evaluation in Texas. In Texas 49 hybrids from Riverside, California; Indio, California; and Orlando, Florida were introduced as budwood during the past year; trees propagated from these selections are in quarantine prior to field planting. Trees propagated from budwood introduced in 1959 have been set out in the field. Seedlings from 1958 Indio crosses between rootstock varieties were planted; seedlings from 1959 Indio crosses are growing in the greenhouse.

Plans: Hybridization of loose-skinned types of citrus, early oranges, and various combinations of tangelos, grapefruit and shaddocks will continue to be made. Long-term work on the introduction of cold hardiness from kumquat and the trifoliolate orange into lemons and grapefruit will be pursued on limited scale. Study and evaluation of citrus seedlings and second test selections will be continued. The backcrossing program with dates will be continued at the same level.

Publications: Breeding Citrus for Cold Hardiness. J. R. Furr and W. W. Armstrong, Jr. Fla. State Hort. Soc. Proc. 72:66-71. 1959.

Pollination, Breeding and Selection of Date Palms. R. W. Nixon. First International Technical Meeting on Date Production and Processing (Tripoli, Libya), Background Paper on Date Production: 22-41 (mimeographed) Food and Agriculture Organization of the United Nations, Rome. 1959.

Robinson, Osceola, and Lee--New Early-Maturing Tangerine Hybrids. Philip C. Reece and Frank E. Gardner. Proc. Fla. State Hort. Soc. 72:49-51. Oct. 1959.

Notice to fruit growers and nurserymen relative to the naming and release of three tangerine hybrids. M. W. Parker, U. S. Dept. Agric. A.R.S. Crops Res. Div., Oct. 1959

3. ROOTSTOCK BREEDING AND EVALUATION

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Problem: The industry needs improved citrus rootstocks possessing such characteristics as that of inducing heavy yields of high quality fruit in the scion variety, tolerance to Phytophthora attack, tolerance to high lime soil, saline soil, and to frost. Rootstocks now available and those to be produced in the breeding program need to be evaluated for these characteristics.

Program: Selection, hybridization, and testing of rootstock varieties is a continuing long-term program involving pathological, nematological, physiological and horticultural laboratory and field studies. The work is being done on a regional basis at Orlando, Florida; Weslaco, Texas; and Indio, California, with the cooperation of the State Experiment Stations, citrus nurseries and growers. Hybridization is performed at Orlando, Florida, and Indio, California; selection and testing for tolerance to cold is done at Weslaco, Texas; selection and testing for tolerance to salinity and high lime soil is done at Weslaco, Texas, and Indio, California; selection and testing for nematodes is done at Orlando, Florida; and selection and testing for Phytophthora attack is done at Orlando, Florida, and Indio, California. Field testing of the general performance in combination with scion varieties is done at Weslaco, Texas; Orlando, Florida; and Indio, California. This work involves 3 Federal professional man years.

The propagation of the nursery stock is done without cost to the Government by cooperating citrus nurseries (Ponkan Nurseries at Apopka, Florida; Rio Farms, Inc. at Edcouch, Texas; and the W-N Ranch at Thermal, California).

Progress: Rootstock breeding investigations in California. In California, hybrid seedlings of Eremocitrus glauca, Rangpur lime, Cleopatra, shaddocks, sour orange, citranges and trifoliate orange are being tested for salt tolerance; many open-pollinated seedlings and hybrids are being tested for tolerance to Phytophthora and to high lime soils. The most tolerant plants are selected for further tests and for use in breeding. Apparent progress is being made in introducing tolerance to saline and high lime soils into the trifoliate orange by back-crossing to citranges, and crossing with Rangpur lime, Cleopatra and other mandarins. Small numbers of F-1 hybrid seedlings from 1959 crosses made in pursuance of the program outlined above were planted in the field in 1960.

Rootstock breeding investigations in Florida. Citrus rootstock breeding was initiated in Florida in 1960. Eighteen crosses involving commercially desirable rootstocks and disease-resistant types were made. Greenhouse screening of the progenies for resistance to Phytophthora, burrowing nematode, and tristeza is planned before they are tested in the field for their effect on fruit quality, yield, and cold resistance.

Rootstock evaluation studies in Texas. Results in 1960 corroborate those in previous years showing that when Red Blush grapefruit trees carry exocortis and xyloporosis viruses, the highest yielding trees were those on rootstocks not sensitive to these viruses. Highest-yielding trees set in 1950 were on Precoce de Valence sweet orange, Rough lemon, Citrumelo 4475, Sour orange and Red Blush grapefruit rootstocks. Fruit on Rough lemon rootstock was heavier, larger, thicker in rind, lower in acids and soluble solids, and deeper in red color than fruit on other rootstocks tested.

With Valencia orange trees of the same age, the highest-yielding trees were virus-free trees on sweet lime and Rangpur lime rootstocks; virus-infected trees on these two rootstocks were low yielding. Meyer lemon, Navel, Marrs and Hamlin orange, Clementine tangerine and Orlando tangelo fruits from trees on several different rootstocks were sampled and analyzed for fruit quality during the past year. Characteristics of fruit on trees of Columbia sweet lime were large size, thick rind, low total solids, and low acids. Other rootstock differences were less striking.

Rootstock evaluation studies in Florida. Although the tree size and yield are profoundly influenced by the rootstock variety, results from a 17-year-old rootstock test in Florida revealed that no pronounced correlation existed between the initial tree sizes of nursery trees ranging from 1/2 to 7/8 inches in diameter and ultimate tree size or between initial size and yield within the various rootstocks. The results of the work indicate that, within the range of nursery tree sizes studied, a grower could expect to produce as large and productive orchard trees by planting $\frac{1}{2}$ " nursery stock as by planting the larger sizes.

Following a prolonged dry period in September 1958, Parson Brown and Valencia sweet orange trees on various rootstocks in an experiment on Lakeland fine sand were rated as to their degree of wilting. Marked differences between rootstocks were evident. Sour orange, Rough lemon, and Cleopatra were outstandingly more resistant to the drought than were grapefruit, sweet orange, and Rusk citrange. Unbudded Parson Brown seedlings in the planting also showed severe wilting. Tree sizes on the various stocks indicate that the differences in apparent

drought resistance were attributable to the rootstock effect rather than to a greater or less soil moisture depletion by trees of different sizes.

During the past year 3 additional rootstock orchards involving many rootstocks have been planted on a cooperative basis with commercial growers. The scion varieties are, respectively, Valencia orange, Pineapple orange, and Marsh grapefruit (all nucellar) on 24 kinds of trifoliate orange hybrids.

Nematode tolerance studies in Florida. The U.S.D.A. cooperation with the University of Florida Citrus Experiment Station has continued to screen citrus species, varieties, and relatives for resistance to attack by the burrowing nematode. About 1300 varieties, species, and relatives have been screened to date. Thirty-nine of the varieties from the California collection show sufficient promise for greenhouse growth testing.

During the past year Dr. Harry W. Ford of the Citrus Experiment Station gathered seed from the Belgian Congo. These seed have been received and planted. During the year seed of the 6 promising nematode-tolerant varieties were given to 3 nurserymen for production of seed. In addition, budwood from the original old-line trees of Carrizo, Rough lemon-A, Rough lemon-B, and Clone X were given to all nurserymen requesting them, again to be used for seed producing purposes.

Budwood of Sanguine Grosse Ronde and Pineapple 156 was not cut since both of these trees have tristeza. Budwood from these new sources is being treated in the heat chamber and when demonstrated to be tristeza free will be multiplied and given to the nurserymen upon request.

Large-scale field plantings of nematode-tolerant rootstocks have been started at the U.S.D.A. Florida Citrus Research Foundation Farm at Leesburg and the Minute Maid plantation at Ft. Pierce. In addition, other selections of nematode-tolerant rootstocks budded with commercial tops are prepared for setting out at the property of Dr. R. D. Rands at Lake Wales, a burrowing-nematode-infested grove; at the University of Florida at Gainesville in the rootstock observation block; and at Lucern Park, a Minute Maid grove infested with the burrowing nematode.

Those varieties which have shown enough promise to rate field testing against the burrowing nematode are now being tested for resistance or tolerance to the citrus nematode, another plant parasitic nematode prevalent in Florida orange groves. A special screening tank facility has been set aside for this work. Data from other experiments have indicated that the tolerance exhibited by certain of the sweet oranges

may not necessarily reflect an increased tolerance to nematodes but rather a resistance to certain of the fungi which are allowed to penetrate the roots once the nematodes have paved the way. This is being explored further.

Gamma irradiation of seed to induce nematode tolerance. Large numbers of Rough lemon and Sanguine Grosse Ronde seed have been irradiated with gamma radiation from a Cobalt 60 source. Certain of the Rough lemon seed irradiated in this manner appear to have been altered to some extent. These abnormal Rough lemon seedlings tolerate the burrowing nematode and grow with much increased vigor, as compared with normal Rough lemon seedlings. Plants showing differences have been isolated and grown for production of budwood so that fruit and seed of these plants can be observed.

Plans: Hybridization and testing of rootstock types will be continued and further attempts will be made at crossing some highly salt tolerant and fairly vigorous hybrid selections of *Eremocitrus glauca* with Rangpur lime, Cleopatra, and trifoliate orange varieties. *Eremocitrus glauca* hybrid selections and *Severinia buxifolia* selections (both highly salt tolerant) will be tested for compatibility and general performance when used as stocks for grapefruit, orange and tangerine. In Florida further attempts will be made to cross-pollinate all of the burrowing-nematode-tolerant rootstocks with trifoliata for cold hardiness and with the Yuma citrange for *Phytophthora* tolerance. Also in Florida screening of new varieties, species and relatives for nematode tolerance will taper off. Plans are to shift attention to screening the promising hybrids of the rootstock breeding program at Orlando, Florida and Indio, California. Field-scale evaluation of the now known nematode-tolerant rootstocks will become the predominating activity of the rootstock program until such time as new hybrid material becomes available for preliminary testing.

Publications: Rootstock Effects on the Physical Characteristics and Chemical Composition of Fruit of Six Citrus Varieties in Texas. R. E. Woodruff and E. O. Olson, Jour. Rio Grande Valley Hort. Soc. 14; 77-84. 1960.

Quality of Red Grapefruit on Old-line Trees on Xyloporosis- and Exocortis-Tolerant Rootstocks. W. C. Cooper and Bruce J. Lime. Jour. Rio Grande Valley Hort. Soc. 14; 66-76. 1960.

Promising Rootstocks That Tolerate the Burrowing Nematode. H. W. Ford, W. A. Feder, and P. C. Hutchins. Proc. Fla. State Hort. Soc. 72:96-102. 1959.

Relation of Citrus Nursery Tree Size from $\frac{1}{2}$ to $\frac{7}{8}$ Inches to Ultimate Size and Production. F. E. Gardner and G. E. Horanic. Proc. Fla. State Hort. Soc. 72:102-105. 1959.

Relative Wilting of Orange Trees on Various Rootstocks. George E. Horanic and F. E. Gardner. Proc. Fla. State Hort. Soc. 72:75-77. 1959.

Citrus Varieties, Hybrids, Species, and Relatives Evaluated for Resistance to the Burrowing Nematode, *Radopholus similis*. H. W. Ford, W. A. Feder, and P. C. Hutchins. Plant Dis. Reprtr. No. 6, p. 405. 1960.

B. Physiology and Nutrition

4. NUTRITION STUDIES OF CITRUS AND DATES

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Problem: Continued research on fertilization practices is necessary in order to constantly improve production practices leading to maximum yields of high-quality fruit in the various areas used for growing subtropical fruit crops. In Florida, though much progress has been made in citrus fertilization, there is still a need for more information on sources, rates, ratios, placement and timing of fertilizers on more types and varieties of citrus than has been studied so far. Fundamental information on the absorption processes and function of various chemical elements is needed also for intelligent understanding of fertilization requirements. The light sandy soils of Florida are notorious for their lack of native fertility. Deficiencies of all known essential elements have been encountered in citrus culture. The heavy metal elements, copper, zinc and manganese, are so extensively used in mature groves that a case of deficiency is rarely encountered. Yet there is practically no reliable information as to how best to apply these elements. Exuberant use of copper led to serious copper toxicity (1952 report). Foliage sprays of these elements, while efficient nutritionally, aggravate the control of certain insect pests and are therefore objectionable. In the arid portions of the citrus-growing regions of Texas, Arizona and California, problems of irrigation, salinity and fertility pose a constant challenge for research to improve the growth and production of both citrus and dates. Sound information in all these lines with slow-growing tree crops is difficult to achieve and requires relentless effort over a period of many years in order to solve even seemingly simple problems.

Program: A long-range program of laboratory and field type nutritional studies with citrus is carried on at Orlando, Florida; Weslaco, Texas; and Indio, California in cooperation with commercial growers. A similar program with dates is carried on at Indio. The work on citrus and dates involves about 3 Federal professional man years.

Progress: Heavy-metal fertilization in Florida. In 1954 several elaborate field experiments were established in which many different ratios of copper, zinc and manganese were incorporated in the ground in young citrus orchards in an attempt to find a favorable combination to fortify the low natural soil supply of these elements and see if root absorption would adequately supply the tree for many years from a single application. Extensive leaf analysis study 5 years after application shows that absorption of all 3 of these elements tends to parallel the applied rate. Many combinations show promise of satisfactorily supplying the nutritional requirements of the trees for many years to come. Somewhat contrary to previous experiences, absorption of zinc appears to be entirely adequate and indicates that past failures of curing zinc deficiency by soil application were due to failure to work zinc down to a depth where roots can contact it. In this case, an initial plowing to a depth of 6 or 7 inches seems to have been satisfactory. Rates of 30, 75 and 150 pounds per acre of copper, zinc and manganese, respectively, look very good and even half these amounts are still maintaining the trees in a satisfactory range of nutrient level. As a result of these findings, several large-scale pre-planting additions of these metals are being made commercially.

Phosphate toxicity in Florida. In 1956 it was reported that moderately high rates of superphosphate resulted in reduced root growth in the upper soil depths under field conditions. Studies with citrus seedlings in pots indicate that this is a result of the acidity carried by this material. Incorporation of lime in the soil does not offset the response since there is poor contact of the acid with the insoluble lime particles and the excess acid persists long enough to damage small roots. However, preneutralization of the acid with any of several soluble bases such as calcium hydroxide or sodium hydroxide rendered the phosphatic material non-toxic. Also equivalent amounts of a strong acid, such as sulfuric acid, were toxic regardless of the presence or absence of phosphate. Furthermore, the toxicity of superphosphate dissipates with time as the acid is gradually neutralized by the soil or the lime in the soil. This only takes a few days, but roots are killed in the process. From the practical standpoint it appears that the process of ammoniating

superphosphate, as is usually done before using on citrus, probably neutralizes most or all of the free acid so that the superphosphate used in most fertilizers is rendered non-toxic.

Other work on citrus nutrition in Florida. Studies are in progress on nitrogen source, rates and placement on oranges, young tree fertilization, zinc and manganese sources in soil, soluble foliage fertilizers, and comparison of nutritional behavior of nucellar and clean old lines when grown under identical conditions. The work has not progressed far enough for conclusive results.

Nitrogen fertilization in California. During the first season after planting grapefruit trees on light sand, water was applied at three frequencies--once, twice or thrice weekly--and ammonium nitrate was applied at weekly or monthly intervals though the totals were the same. Total new shoot growth improved with increasing frequency of irrigation and, except for trees irrigated only once a week, improved with the more frequent fertilization.

In the nitrogen fertilizer rate test on non-bearing date palms greatest growth was made by trees that received the most nitrogen, but differences were not statistically significant.

Plans: Citrus and Date Mineral Nutrition Research will be carried on at approximately the same level as heretofore.

Publications: The Relation of Growth, Yield and Fruit Quality of Deglet Noor Dates to Variations in Water and Nitrogen Supply and to Salt Accumulation in the Soil. J. R. Furr and W. W. Armstrong, Jr. Date Growers' Inst. Rept. 36:16-18. 1959.

The Relation of Potassium Nutrition to Citrus Fruit Size and Quality. P. F. Smith and G. K. Rasmussen. Proc. Amer. Soc. Hort. Sci. 74:261-265. 1959.

How to Grow Quality Fruit by Fertilization. Paul F. Smith, Citrus Magazine 22-3:16, 17, 23. 1959.

Field Trials on the Long-Term Effect of Single Applications of Copper, Zinc and Manganese on Florida Sandy Citrus Soil. P. F. Smith and G. K. Rasmussen. Proc. Fla. State Hort. Soc. 72:87-92. 1959.

Pot Studies on the Toxicity of the Superphosphates. G. K. Rasmussen and P. F. Smith. Proc. Fla. State Hort. Soc. 72:71-75. 1959.

5. CITRUS CLIMATE RELATIONSHIPS

Problem: The obvious differences in the growth and development physiology of citrus in the different regions of the United States makes it desirable to determine what elements of climate and environment condition such growth responses as thickness of rind, acid and sugar content of fruit, length of period required for fruit to mature and ripen, earliness and degree of dormancy and cold hardiness during the winter. If data can be accumulated to facilitate a clear understanding of the widespread interrelationships between growth, development and physiology of citrus and the various elements of their climatic environment, it would be of great importance to the growing of high-quality fruit and in the development of cold-hardy trees.

Program: A long-range program of laboratory and field type physiological studies is being carried on to accumulate sound information on this problem. The laboratory work is carried on at Weslaco, Texas where greenhouses, cold chambers, climate control facilities (citrotron), a portable tree freezer, and biochemical laboratory are available. The field-type studies are carried on at Orlando, Florida; Weslaco, Texas; Phoenix, Arizona; and Indio and Riverside, California in cooperation with the Agricultural Experiment Stations and commercial growers. The work involves between 3 and 4 Federal professional man years.

Progress: Effect of scion and rootstock variety on cold hardiness (Texas). Satsuma mandarin, Red Blush grapefruit and Mexican lime trees on several rootstocks were frozen in the field with a portable freezer. The satsumas were cold hardy, the grapefruit intermediate and the limes cold sensitive; trees of all 3 varieties on sour orange rootstock were more cold hardy than those on Mexican lime, trifoliate orange, and Citrus macrophylla rootstocks.

Effect of cool temperature on cold hardiness (Texas). Young Red Blush grapefruit seedlings were cold hardened in a 40° greenhouse for varying lengths of time. This hardening appeared related to dormancy to some extent, as indicated by a decrease in cambial activity of the plants; but no change in the cell sap concentration of the leaves was noted. Exosmosis readings were strongly correlated with the degree of injury in freezing tests.

Effect of day length on cold hardiness (Texas). Day length affected growth and cold hardiness of citrus. Seedlings of Red Blush grapefruit, sour orange, and rough lemon and young budded trees of Red Blush grapefruit on sour orange rootstock produced more growth when given 16 hours of light than when given 8 hours of light. Plants receiving 16 hours of light were more succulent and less cold hardy.

Chilling injury on citrus reproduced under controlled conditions (Texas). During cool weather in Texas, chilling injury in field-grown citrus has been apparent in certain species. It appears as an irregular pattern in the leaves, much like the leaves had been partially bleached. This injury was reproduced in the Texas citrotron by holding citrus seedlings at constant 40°F. for several weeks.

Freezing curve patterns for citrus leaves determined (Texas). Changes in leaf temperatures during freezing of nucellar Red Blush grapefruit budded on Cleopatra mandarin rootstock and seedlings of Duncan grapefruit, Rangpur mandarin-lime, rough lemon, Troyer citrange, and sour orange were recorded. A characteristic rise in the leaf temperature, apparent as freezing was initiated, was followed by a reduction in temperature after the leaf was fully frozen. Freezing curve patterns for the six species tested were similar in shape. Leaves which did not freeze did not show the characteristic rise in temperature.

Other work on cold hardiness in Texas. Other studies in progress include studies with chemicals reported to have value in preventing frost damage, chemicals which have been reported to affect the growth of plants, studies on the relationship between dormancy and cold hardiness, investigations on the differences in the biochemistry of cold-resistant and cold-susceptible plants, and the relationship between climate, dormancy, and cold hardiness of various citrus species.

Regional climatological studies. Progress in this project consists principally in establishing 2 citrus climate stations in Florida and one in Texas and in making arrangements with the University of California and the University of Arizona to use the climate data from their already-established climate stations at Phoenix, Arizona, and Indio, Riverside, Santa Paula, Del Mar and Lindsey, California. These climate stations in all instances are located in a Valencia orange grove, the trees being approximately 20 years old and grown on sour orange rootstock. Arrangements have been made to obtain measurements on tree growth, tree dormancy, bloom, seasonal distribution of growth, fruit quality, fruit growth and ripening concomitantly with the climate data. At 3 of the climate stations--Orlando, Florida; Weslaco, Texas; and Indio, California--16-multipoint electronic recording thermometers have been installed to obtain continuous records on leaf, fruit, bark and root temperatures. All data will be assembled and analyzed at the U. S. Horticultural Station at Orlando, Florida.

That climate has a pronounced effect on breaking of dormancy of citrus species is indicated by data collected in the Rio Grande Valley of

Texas during the spring of 1960. Most limes, lemons, oranges, grapefruit, and tangelos were actively growing by February 1. Mandarins and citrumelos remained dormant 2 weeks longer, while citranges and several other trifoliate oranges remained dormant until the middle of March.

Plans: The cold hardiness work at Weslaco will be carried on at approximately the same level as heretofore, with perhaps a little greater emphasis being placed on biochemical aspects of cold hardiness. The climatology research is planned to continue for a period of 5 years during which time the data will be analyzed and an attempt made to integrate the behavior of the tree under field conditions under the 9 climates.

Publications: Changes in Citrus-Leaf Temperatures During Freezing. Roger H. Young and A. Peynado. Rio Grande Valley Hort. Soc. 14: 53-57. 1960.

Effect of Rootstock-Scion Combination and Dormancy on Cold Hardiness of Citrus. Roger H. Young, A. Peynado, and W. C. Cooper. Rio Grande Valley Hort. Soc. 14:58-65. 1960.

Winter Temperatures of 3 Citrus Areas as Related to Dormancy and Freeze Injury of Citrus Trees. William C. Cooper and Ascension Peynado. Proc. Am. Soc. Hort. Sci. 74:333-347. 1959.

Cold Hardiness in Citrus as Related to Dormancy. William C. Cooper. Proc. Fla. State Hort. Soc. 72:61-66. 1959.

C. Cultural Practices

6. IRRIGATION AND THINNING OF DATES

Problem: Continuous research on cultural practices is necessary in order to constantly improve production practices leading to maximum yields of high-quality dates. Cultural practices are thought to influence skin separation of soft varieties of dates. The crop load affects fruit size, quality and yield, and accumulation of salts in the soil profoundly affects growth, fruit quality and yield.

Program: Studies are being conducted on dates at Indio, California, to determine the influence of fruit thinning and other practices

on the severity of skin separation; the influence of size of crop on fruit size, quality and yield; and the relations of soil type, depth to water table and irrigation practice on salt accumulation in date gardens. About 1 Federal professional man year is expended on this program.

Progress: A survey of Khadrawy date gardens, just before the first picking, showed 25 percent of the fruit to be affected by skin separation. A test is now being conducted to determine the influence of severity of fruit thinning on skin separation of Khadrawy and Barhee varieties of date. Deglet Noor palms thinned to a crop load of 40 to 60 percent of the bunches set had slightly larger fruit than those allowed to mature 80 to 100 percent of the bunches, but total yields and fruit quality were appreciably lowered by the heavier thinning.

In a survey of soil salinity in date gardens in the Coachella Valley it was found that salts tend to accumulate to injurious levels in heavy, stratified soils, in those with a high water table, and in soils irrigated with 6 or less acre-feet of water per year.

Plans: The work on dates will be carried on at about the same level as before. At the request of the date industry, work will be renewed on the relation of frequency of picking to quality of fruit produced.

Publications: Root Distribution of Khadrawy Date Palms in Relation to Frequency of Irrigation. W. W. Armstrong, Jr. and J. R. Furr. Date Growers Inst. Rept. 36:13-15. 1959

D. Disease and Nematode Control

7. DISEASE CONTROL

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Problem: Continuous research on virus diseases is necessary because of the nearly universal occurrence of viruses in commercial citrus groves which reduces tree growth and vigor. Although the Budwood Certification Program has contributed greatly to control of some virus diseases, new research techniques are needed to find better means of detection and control of these diseases. The fungus disease *Phytophthora* continues to be the major killer of trees in Florida, California and Arizona. In California much progress

has been made in the etiology of the causal organism, Phytophthora, and in the screening of citrus species as rootstocks for tolerance to Phytophthora. There is still a need for more work along this line in California and for the establishment of an extensive Phytophthora research program in Florida. Although footrot is a major killer of trees in Florida, little is known of the etiology of the Phytophthora species in Florida. Sound information in all these lines requires relentless effort over a period of many years.

Program: A program of continued fundamental and applied research on diseases is being conducted by the Department of Agriculture on a regional basis in cooperation with the State Agricultural Experiment Stations in California, Arizona, Texas and Florida and the Federal laboratories at Indio, Weslaco and Orlando, utilizing about 6 Federal professional man years annually.

Progress: Tristeza virus strain investigations in Florida. Previous reports have indicated that variable ratios of tristeza virus strain mixtures could occur within a single host and that the different citrus species and heat could influence the ratios of the virus strains. The reports from the Belgian Congo indicate that Valencia oranges on supposedly tristeza-tolerant Rough lemon rootstocks are declining and have serious stem pitting. This has revived interest in tristeza virus strain studies. In addition, reports from Brazil indicate that a similar decline and stem pitting is occurring on Pera sweet orange tops on other rootstocks that were considered tolerant to tristeza. The serious implications of this situation prompted the sending of T. J. Grant to Brazil to review the cooperative tristeza experimental planting and to make a survey of conditions in other field plantings.

Heat treatment of plants. Heat treatment of plants infected with tristeza and psorosis viruses has been an effective means of obtaining budwood free of these viruses. Tests of heat treatments of plants with xyloporosis and exocortis virus are still in progress but indications are that heat effects are not the same for xyloporosis as for tristeza and psorosis viruses.

Transmissible variegation of citrus. Transmissible variegation of citrus was found on a few citrus field trees in Florida. The variegation virus was tissue transmitted in the greenhouse to a considerable number of citrus varieties. Symptoms were expressed on inoculated plants when special methods of pruning and defoliation were employed.

Mechanical method of juice transmission of a citrus virus. Through the combined use of freezing, with additions of sucrose solution and activated charcoal, it has been possible to transmit by juice from citrus to citrus the variegation virus strain in conjunction with the psorosis virus strain. This finding opens up for the first time a field of investigational work not possible when the virus can only be transmitted by means of tissue grafts. Tests can now be undertaken more logically to determine the variegation virus' tolerance to dilution, its aging in vitro, and its thermal death-point, as well as studies of its purification, concentration and characteristics under the electron microscope. These studies require time, but they are now possible for this one citrus virus and there is an opportunity to apply the same technique to other citrus viruses.

Histochemical detection of exocortis virus. Preliminary results with the histochemical test for exocortis virus developed by Childs et al, 1957, reveal that exocortis virus is extremely widespread in commercial trees in Florida; e.g., more than 90% of commercial trees. By this test it was determined that certain stunted Valencia orange trees on alleged Rough lemon were in fact on sour lemon (Eureka or similar type) and furthermore that the sour lemon rooted trees were infected with exocortis. Confirmation of these results is underway by the usual bud transmission test, but may require 2 years or more (note the saving in time).

Histochemical detection of xyloporosis virus. Certain U.S.D.A. hybrid citrus trees, 3 years old, were retarded and exhibiting a bark gumming condition. Histochemical tests revealed that the stunted trees were infected with xyloporosis. It is not known by what means these hybrid trees became infected, but histochemical tests reveal the virus in a matter of days whereas the usual index test by bud transmission of the virus would normally require 1 to 5 years.

Histochemical detection of stubborn virus. Preliminary histochemical examination of bark specimens from stubborn trees in Morocco, collected by Childs and Carpenter, 1959, have revealed no diagnostically useful information to date.

Virus-disease control of Persian (Tahiti) lime through seedling lines. The Persian lime is a large seedless lime grown principally in Florida (400,000 boxes in 1957). For many years the Persian lime industry has suffered heavy losses from a complex of systemic bud

transmitted diseases, including xyloporosis, lime bark disease, leaf blotch and fruit sectoring, and blind pocket. Many plantings failed without producing a single commercial crop. In 1952 two hundred and fifty seeds from several tons of concentrate pulp of Persian lime were collected in the hope that a commercial useful lime, free of viruses, could be grown. Seedlings showed leaf characteristics similar to a trifoliate orange, grapefruit, sour orange, etc., and some exhibited symptoms of leaf blotch or wood pocket disease, indicating transmission through the seed of that disorder. Only lime-type seedlings were planted. Most were worthless, bearing fruits like goose-neck squash. Two seedling trees, however, are bearing fruit that seem identical with commercial limes in internal and external appearance and in flavor and aroma. The rind oil of the two trees will be compared chemically with that of old-line budded limes. These two seedling lime trees are presumably free of the systemic diseases of the old-line trees, thus providing a source of lime budwood of increased life expectancy and productiveness and making it possible to grow lime trees on the more desirable rootstocks such as *P. trifoliata*, citranges, Rangpur lime, etc.

Stubborn disease studies in California. Indexing of 39 stubborn-affected trees for virus content has revealed no evidence of tristeza, psorosis, or vein enation, while about one half of the trees carried either cachexia or exocortis. This incidence of cachexia and exocortis, however, was no greater than among trees not showing stubborn disease. None of the 60 species, varieties, or relatives of citrus being studied as possible specific indicator plants for stubborn disease has shown any effect of stubborn. The oldest trees are 5 years of age. Stubborn disease has been observed in Frost nucellar March grapefruit trees in some Coachella Valley commercial groves. This variety has been widely planted in recent years in the hope that it would be free of this virus-like disorder. But it is not known whether it was inadvertently infected somewhere along the line in the process of propagation.

Stubborn disease survey of Morocco. Stubborn disease in Moroccan citrus orchards was studied in 1959 by personnel of the Indio and Orlando stations in cooperation with Moroccan officials. The disease is widespread and of substantial economic importance. The symptoms and effects of the disease are comparable to those observed in California and Arizona, with the exception of a symptom designated as "stylar end greening," in Morocco and often associated with the development of fruit color at maturity. This symptom will be studied in the United States during the next harvest season.

Collapse of young trees in California. More than 1500 young citrus trees on Rough lemon rootstock collapsed and died in Coachella Valley between July and October 1959. The immediate cause of collapse was invasion of the rootstock by fungi, principally species of *Fusarium*. However, the fungus invasion was probably secondary. The primary cause was presumed to be chemical damage to roots by ammonia, nitrites, and excessive salt concentration which allowed *Fusarium* to enter. All of these toxic products may have been involved where dry sewage sludge was used in the planting hole, a practice used in the three orchards that suffered seven-eighths of the losses. Ammonia and nitrites were probably involved where heavy side dressings of animal manures were used. Over-irrigation also occurred and perhaps aggravated the damage.

Dormant root initials in citron. Dormant root initials that could easily be confused with pitting resulting from virus infection were observed in citron stems in work at California. These dormant root initials may persist for 3 years or longer and then emerge as roots if held under conditions suitable for rooting. The root initials were found in 11 varieties of citron and in some citron hybrids.

Exocortis virus studies in California. Both Rangpur lime and trifoliolate orange were used as indicator plants in indexing trials for exocortis. Of 25 candidate trees indexed, 13 expressed exocortis on both Rangpur lime and trifoliolate orange and 6 have expressed exocortis only on Rangpur lime. The expression of exocortis is often delayed on the slower-growing trifoliolate orange and, in addition, Coachella Valley soils are not especially favorable for this species.

Phytophthora screening studies in California. Rooted cuttings of 52 citrus seedling selections, made from among the survivors of the *Phytophthora* root-rot tolerance tests of 1956-58, were subjected to the tolerance test in 1960. In 10 selections there was 100 percent survival of the cuttings; in 18 selections more than 80 percent of the cuttings survived. These 28 selections are being propagated at Indio and Brawley on large seedlings to hasten fruiting so that seed will be available for further disease and horticultural studies.

Phytophthora studies in Florida. Cultures of *Phytophthora* sp. which are the result of a limited survey of Florida groves are being maintained in the laboratory. These cultures have been obtained from bark samples, soil samples, and feeder roots. At present there are five such cultures and they are believed to be *Phytophthora*

parasitica. A culture was sent to L. J. Klotz, University of California, on February 15, 1960, for identification, but at this date no answer has been received. These cultures are being checked periodically for pathogenicity. A composite of all isolates will be used for inoculating seedlings in the greenhouse. The Klotz & DeWolfe aeration method is being used in the greenhouse to infect trifoliata, sweet orange, sour orange, Rough lemon and an unknown lemon and seventeen crosses of Rangpur x Citrus pectinifera and one cross of Rangpur x Swingle Poncirus trifoliata, totaling some 600 plants. Longevity checks of the viability of the fungus are now being made from soil collected from a nearby grove of foot-rot-infected trees. This soil was originally proven to yield the fungus in 7 out of 10 checks. Since then a portion of the same collection has been kept wet and another portion kept dry. Periodic checks will be made to determine for what length of time this soil will continue to yield Phytophthora.

Plans: Citrus disease research will be carried on at approximately the same level as heretofore.

Publications: Present Status of Heat Treatment of Citrus Viruses. T. J. Grant, J. W. Jones, and G. Norman. Proc. Fla. State Hort. Soc. 72:45-48. 1960.

Infectious Variegation of Citrus Found in Florida. T. J. Grant. Plant Dis. Repr. 44(6):426-429. 1960.

Mechanical Transmission of the Infectious Variegation Virus of Citrus. T. J. Grant and M. K. Corbett. Nature (London). 1960.

Present Status of Investigations on Stubborn Disease of Citrus in the United States. J. B. Carpenter. In Citrus Virus Diseases, edited by J. M. Wallace, Univ. Calif. Div. of Agr. pp. 101-107. 1959.

Collapse of Young Citrus Trees in Coachella Valley. J. B. Carpenter, L. J. Klotz, T. A. DeWolfe, and M. P. Miller. Calif. Citrograph 45:4, 19-21. 1959.

Evaluation of Rootstocks for Valencia Orange Trees Following Inoculation Under Screenhouse Conditions With a Severe Strain of Tristeza Virus. E. O. Olson. Jour. Rio Grande Valley Hort. Soc. 14:29-32. 1960.

Xyloporosis (Cachexia or Fovea) Disease of Murcott Honey "Orange" in Texas. E. O. Olson. Jour. Rio Grande Valley Hort. Soc. 14:26-28. 1960.

8. NEMATODE CONTROL

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Problem: Spreading decline of citrus has been attributed to the burrowing nematode. Certain findings indicate that this disease may actually involve nematodes and fungi acting as a complex and also that citrus is damaged economically by several other species of nematodes. Laboratory, greenhouse and field data are needed to resolve these problems and to determine whether the other plant parasitic nematodes that attack citrus are also members of disease complexes. There is a need for more information of a basic nature such as how nematodes live in grove soils, how they and associated organisms attack citrus roots, and how nematode associated diseases may be controlled in the grove. In addition, the development of a rootstock tolerant or resistant to attack by nematodes would be useful.

Program: A continuing program of basic and applied research is being conducted at Orlando, Florida; Weslaco, Texas; and Tempe, Arizona in cooperation with the Texas and Arizona Agricultural Experiment Stations and commercial growers. The program involves about 4 professional Federal man years annually.

Progress: Nematocide screening. During the past year 212 new chemicals obtained from the industry and from the Pesticide Chemicals Research Branch, ERD, ARS, were evaluated for nematocidal activity. Only one of these materials appears to show any promise as a bare-root dip that is not toxic to living roots. Several others were nematocidal but phytotoxic.

Chemical treatments for spreading decline. In a greenhouse experiment, evidence has been secured that indicates fungi contribute to spreading decline symptoms. Growth response was also observed in seedlings treated with a nematocide or with an experimental fungicide. Since this latter material has no effects on nematodes, the improved growth following treatment with it is interpreted as evidence that the "decline" is caused partly by nematodes and partly by fungi. The results also show that further work is needed to refine dose rates of fungicides and to determine intervals between treatments.

Field fumigation tests. Field tests in spreading decline areas are underway, using low dosages of DBCP (Nemagon or Fumazone), ethylene dibromide and experimental materials, that have shown promise in greenhouse tests. Growth responses have not yet been observed. Combination nematocide-fungicide treatments are being field tested in three areas, but growth responses have not yet been observed.

Nematocides for ornamental nursery stock. Ornamentals infected with the burrowing nematode are factors in the nematode's spread to commercially-grown citrus. At the present time certification of ornamentals as nematode free depends upon samples being negative for nematodes. Chemical methods that were effective in freeing plants of nematodes could be substituted for periodic sampling.

Chemical drenches of soil do not move properly in heavy organic mixtures used in commercial ornamental beds. Work that is underway with an experimental bare-root dip used on cuttings immediately prior to planting shows indications of being a promising practical alternative that can be used by commercial growers.

Nematode-fungus complex. Duncan grapefruit seedlings have been inoculated with clean (fungus-free) nematodes alone, fungi alone and nematodes plus fungi. No symptoms occurred on those plants inoculated with clean nematodes; severe symptoms occurred on those inoculated with nematodes plus fungus. The fungus used was three strains of *Fusarium* sp. and the nematodes were grown aseptically in tissue culture. This work is now being repeated, using Rough lemon as the host plant and *Fusarium* and *Phythium* as the fungus.

Nematode migration. Greenhouse studies to measure the ability of the burrowing nematode to move in soil and into roots have been completed. Three separate tests, observed over a period of two years, indicate that the nematode moves at a maximum rate of 9.4 inches per month and 42 inches in 7 months along the root systems of citrus seedlings.

Assay in relation to migration. Fungi, especially *Fusaria*, are found in both clean roots and those infected with the burrowing nematode, but the highest numbers occur in roots infected with the nematode for the longest period. Thus, quantitative differences exist in fungus populations behind and ahead of the margin, the higher numbers being associated with the presence of plant-parasitic nematodes within the roots.

Biological control studies. Studies are being continued on the nematode capturing fungi which are present in Florida citrus groves. These fungi are being recovered, cultured, and cataloged for future use. Techniques have been devised for assaying the activity of these fungi as nematode capturing agents in various types of citrus soil. Highly efficient clones of certain of these fungi have been selected. The active factor which induces ring formation in the nematode capturing fungi has been found in culture media in which large numbers

of saprophytic nematodes have been grown. This material has been isolated in crude form and attempts are being made to combine it with fungus spores to be used in various types of pot scale studies.

Tissue culture work. Tissue cultures of excised okra roots have proven to be excellent hosts for the burrowing nematode. Huge numbers of aseptic burrowing nematodes have been reared in these cultures. These nematodes are extremely useful in inoculation studies involving the fungus-nematode complex work. The burrowing nematode also lives on okra root callus. This provides us a simpler medium for growing large numbers of aseptic burrowing and other types of nematodes.

Plans: The fungus nematode complex studies will be enlarged to include studies on some of the tolerant rootstocks as well as Rough lemon and Duncan grapefruit. Attempts will be continued to produce by selection more efficient nematode capturing fungi. The tissue culture work will be expanded, since the number of nematodes grown in these small tissue cultures requires a tiny fraction of the space which is necessary if the same number of nematodes are reared in the greenhouse on growing plants in the usual manner. Fundamental studies on the effect of nematocides, the metabolism of nematodes, and citrus root tissue will be initiated. Work on practical chemical control in citrus will be expanded during the coming year. Other aspects of the program will be continued at approximately the same level as heretofore.

Publications: Freeze-Drying of *Harposporium anguillulae* Lohde in its Nematode Host. William A. Feder and C. L. Duddington. Nature 182:767-768. 1959.

Heterocaryotic Nature of Ring Formation in the Predaceous Fungus *Dactylella doedycoides*. William A. Feder, C. O. R. Everard and C. L. Duddington. Sci. 131(No. 3404) 922-924. 1960.

Effective Increase in Nematode Populations by the Addition of Aureomycin. C. O. R. Everard and William A. Feder. Nature 184: 1887. 1959.

E. Insect Control

9. FRUIT FLIES AND THEIR CONTROL

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Problem: The recent trapping of a single oriental fruit fly in southern California, the further movement of the Mediterranean fruit fly into new areas of Central and South America, and frequent interception of fruit fly infested fruits or vegetables in the luggage of travelers arriving at our ports of entry again dramatically illustrate the constant threat of fruit fly invasion confronting our subtropical agriculture and need for a continuing strong fruit fly research program. Our protection against these serious pests depends upon the availability of highly effective, low cost detection methods, quarantine treatments and eradication procedures that can be applied to emergency situations with minimum disturbance of trade or inconvenience to the public.

Program: This basic and applied research is conducted in cooperation with the Hawaii and California Experiment Stations, Hawaii State Department of Agriculture and Conservation, Pineapple Research Institute, and Hawaii Sugar Planter's Association Experiment Station in Hawaii, and with the Mexican Government in Mexico. The support and cooperation of the U. S. Navy and Trust Territory of the Pacific have been prerequisites for the development of special tests of male annihilation and sterile fly release eradication techniques on Western Pacific Islands. Approximately 18 man-years of Federal professional service annually are assigned to the fruit fly research program.

Progress: Fruit Fly Detection Methods. The search for better lures continued to receive much attention. In Hawaii screening tests approximately 40 of 930 synthetic compounds showed sufficient promise as attractants for male fruit flies to justify further experimentation. However, none of the Medfly attractants was as good as trimedlure, discovered slightly more than a year ago. Methyl eugenol was better than any of the new oriental fruit fly lures. A significant event in Hawaii was the finding of an unusually strong melon fly male attractant, now known as cue-lure. This material was 7 to 12 times more effective than anisylacetone, the best previous attractant for this species. Procedures for using trimedlure, cue-lure and methyl eugenol in the same plastic trap were developed. The best performance was obtained when 3 ml methyl eugenol and 2 ml cue-lure plus 1% dibrom were applied to one wick and 3 ml trimedlure without insecticide to an adjacent wick.

Trimedlure and cue-lure are attractive to and consumed by sexually immature males. These materials also have better residual effectiveness than those previously available.

Only 2 of 784 compounds, screened on the Mexican fruit fly in Mexico showed promise, i.e., ammonium sulphide and ammonium polysulphide.

The lack of strong Mexican fruit fly attractants that can be used in dry traps in Mexican fruit fly detection programs has made it necessary to give increasing thought to means of improving the performance of liquid lures. Borax was outstanding among 20 compounds evaluated for possible ability to prevent color changes in Staley's Insecticide Bait (SIB 7) associated with the development of microorganisms and decomposition of captured specimens. When this material was used at a 1% rate, catches were not adversely affected and the number of extraneous insects was reduced by about 30%. In Hawaii, the borax SIB 7 lure seemed to perform well on melon fly females but it was not as attractive to oriental fruit fly females as the standard enzymatic protein hydrolysate - ammonium chloride liquid lure.

More than 100 fermentation liquors were supplied by the Northern Utilization and Development Division, including 11 that were promising in Hawaii tests. Of these, 2 were considerably more attractive to melon fly and oriental fruit fly females than the enzymatic protein hydrolysate-ammonium chloride lure. One of the fermentation products was about equal to the standard fermenting lure in Mexican fruit fly tests.

Liquid traps made of acrylic plastic performed as well as, if not slightly better than, standard glass traps in tests in citrus and mango orchards in Mexico. Etching or cloudy deposits on the plastic were noted only where exceptionally hard water was used to prepare the lures.

Insecticides for Fruit Fly Control: The search for more effective and satisfactory insecticides for fruit fly control has been continued, both in Hawaii and Mexico. In Hawaii, 27 candidate insecticides were tested against the three species of fruit flies present there. One of them, known under the code name Bayer 34098 proved to be several times as toxic as malathion in small-scale tests. This and another closely related compound are outstanding among the new insecticides. Both are less damaging to auto finishes than most of the other materials. This is an important consideration in any eradication program involving use of aerial sprays. Of the other effective materials, only Guthion is relatively non-injurious to the new-type auto finishes.

In Mexico, 68 compounds were laboratory-tested against the Mexican fruit fly. Only one seems worth further attention. Large-scale tests of the use of malathion, applied by airplane, with and without a protein hydrolysate bait, confirmed earlier conclusions that the bait increases considerably the effectiveness of the insecticide. A new insecticide, "Baytex", which has low toxicity to warm-blooded animals, has considerable promise as an insecticide for the Mexican fruit fly.

Soil Insecticides for Mexican Fruit Fly: The field cage tests with soil toxicants for the Mexican fruit fly in the State of Morelos are now in the fifth year. Tests in a citrus orchard in Vera Cruz, comparing emulsifiable, wettable powder and granular formulations of endrin and dieldrin with granular heptachlor, are still in the first year of trial. At 196 days, dieldrin granular at 5 lbs. was the least effective with 60 percent kill, and heptachlor granular was the most effective with 91 percent mortality.

The first field tests with soil toxicants for the Mexican fruit fly, made in two blocks of 1,000 grapefruit trees, each in semi-isolated orchards in Nuevo Leon, have given inconclusive results thus far.

Treatment of Fruits to Destroy Fruit Fly Infestations: The possibility of introducing ethylene dibromide into a fumigation chamber by the use of an aerosol containing this fumigant was investigated in Hawaii and Mexico. At the latter location in small chambers, this method worked out well, giving good distribution of the gas and complete mortality of the Mexican fruit fly. Large-scale tests in a citrus packing house in Texas have been started. Preliminary results indicate that the aerosol release mechanism is in need of further development. Ethylene dibromide residues were well within the tolerance of 10 parts per million 48 hours after the fumigation; in most cases the residues were below that figure in an even shorter time.

In Hawaii, the introduction of ethylene dibromide from aerosol bombs was also found to be as effective as the evaporation of liquid ethylene dibromide over a hot plate. Ethylene dibromide treatment now recommended for the treatment of papayas and certain other fruits and vegetables in Hawaii also appears to be effective in destroying fruit fly in tangerines, oranges, and guavas. Methyl bromide fumigation of several varieties of island tomatoes was found to delay ripening by one or two days. Only sound fruit tolerated fumigation. Williams Hybrid, a Cavendish banana mutant from Australia, showed tolerance to ethylene dibromide and methyl bromide fumigation. Previous tests with a Cavendish variety showed that this fruit tolerated EDB fumigation only when grown wrapped. Williams Hybrid was grown unwrapped. Avocados varied greatly in tolerance to fumigation with EDB or methyl bromide.

Further work has also been done with dips containing ethylene dibromide. Methods are being developed to permit continuous use of such dips by replacing the EDB loss in the dip either by continuous injection or by monitoring at short intervals. Using high initial concentrations has also proved useful in prolonging the effective life of the bath. A dipping method of treatment would be especially useful to the small producer.

New Approaches to Fruit Fly Control and Eradication. A large-scale eradication experiment involving use of an attractant to eliminate males from an isolated fruit fly population on the Bonin Islands is now getting underway. Cane fibre board wafers saturated with methyl eugenol, a powerful male oriental fruit fly lure, will be ejected from an airplane at biweekly intervals at the rate of 70 per square mile. The methyl eugenol contains dibrom which kills the flies feeding on the lure. Annihilation of males before they become sexually mature is expected to result in eradication within a few generations.

Preparations for a large area sterile fly release experiment on Rota with both the melon fly and oriental fruit fly are also in their final stages. Expectations are that the first air drops of irradiated flies can be made by November, 1960. Vital requirements of this procedure are effective low cost methods for rearing large numbers of flies. With recent improvements, which included a modified plastic lemon technique for collecting melon fly eggs, production costs have been reduced to about \$235 per million. Methods for manipulating and handling flies during transportation, treatment, fly holding and distribution phases of the sterile male experiment, as well as factors that may have a bearing on the success of the test, have also received intensive study in recent months.

During the past year approximately 25 million Mediterranean fruit fly pupae were used in Hawaii in a pilot sterile fly experiment. In the latest evaluation, infestations in Jerusalem cherry in the release area were 40 to 90% lower than during a comparable period last year. In plum and apricot, the reductions were 98 and 90%, respectively.

In pilot tests on 2 semi-isolated properties in Morelos, Mexico, nearly 1/2 million sterile Mexican fruit flies have been allowed to emerge. As yet there has been no evidence of a reduction in infestation associated with the presence of this small number of sterile flies. In the laboratory, overflooding at a ratio of 50 to 1 resulted in almost total suppression of the reproduction potential of normal flies.

Chemical sterilants, hormones, and other materials capable of influencing reproduction and development of fruit flies afford an unusually promising approach to fruit fly control. Such materials can be administered effectively in the field in combination with protein hydrolysate baits or strong lures. In Mexico, 10% of 175 candidate

chemical sterilants curtailed reproduction of the Mexican fruit fly. Of the materials having the most pronounced effect, one inhibited growth of testes, one the growth of ovaries and 3 the growth of gonads in both sexes. A feeding period of 4 or 5 days on chlorambucil was required for first evidence of sterility in the males. Fertility of eggs from a mixed population on a chlorambucil diet declined to 3 to 5 percent or less by the time the flies were 14 days old.

Colchicine was the most promising of 100 candidate antifertility agents worked with in Hawaii. Some oriental fruit fly egg deposition occurred at a 1 to 3200 concentration of this material in protein hydrolysate but the eggs failed to hatch. Three other compounds, among them, Methotrexate, caused severe malformation of the ovaries and prevented egg deposition. Only Colchicine affected egg fertility.

Biology and Ecology: The hosts of Anastrepha spatulata, a species that was trapped in unusually large numbers in citrus groves in Texas during the 1959-60 harvest season, are not known. In induced oviposition studies, eggs were laid only in the flower buds of an unidentified plant. Grapefruit failed to incite egg-laying.

Catches of the oriental fruit fly were 6% higher on Hawaii, and 22% higher on Maui, in the Hawaiian Islands, than during the previous year. More than 5.5 million male flies were taken in 27 permanently located traps, despite parasitization by Opius oophilus of infestation in guavas of 31 to 65% on Maui and 40 to 56% on Hawaii. In forced oviposition tests, it was possible to rear the oriental fruit fly only from green cotton bolls infested with the pink bollworm. Calamondin, a highly preferred host of the Medfly in Florida during the recent campaign, was not infested when growing in the vicinity of coffee.

Additional evidence of fruit fly capacity for dispersion was obtained in Hawaii and Mexico. In Hawaii, one melon fly was captured on another island at a location 26 miles downwind from release site, movement comparable to that which has already been observed for the Medfly and oriental fruit fly. In a marked fly test in which nearly 5,000 of 100,000 oriental fruit flies released on Maui were recovered, 133 individuals occurred in traps at locations 9 to 11 miles from release site. Dispersal of newly emerged flies was nearly as complete where fruiting hosts were near the release site as it was where hosts were widely scattered, suggesting that food odors may be more attractive than fruit odors during the preovipositional period. In tests on Rota, released sexually immature sterile melon flies moved into the same areas that were attractive to normal ovipositing females.

Gamma radiation from a cobalt source applied at the rate of 6,000 r or less to the egg and larval stages of the oriental fruit fly prevented development to the adult stage. A dosage of 5,000 r prevented similar development in the Medfly. Pupal development was prevented when eggs were exposed to 20,000 r or when 1-day old larvae received 40,000 r. Over 160,000 r were required to prevent pupation of mature larvae, and 100,000 r applied to mature pupae was needed to prevent emergence of adults. A dosage of 10,000 r applied to pupae will insure sterility in emerging males and prevent egg development in females.

An anti-radiation compound in a carrot rearing medium afforded some protection from radiation to mature larvae. Eggs were more resistant when surrounded by water, pure nitrogen or carbon dioxide. Eggs irradiated at temperatures between 32 and 100° F. were equally susceptible.

In radiation tests with infested fruits, last survivors were recorded at the 10,000 r dosage, which gave mortalities (including both immediate and latent mortality) of 99.993 percent for the oriental fruit fly, 99.955 percent for the Medfly and 100 percent for the melon fly. A dosage of 20,000 r has given complete security. Fuerte and Rincon avocados airshipped to Hawaii from California were injured by 20,000 and 25,000 r.

A dosage of 10,000 r administered to larvae and pupae of the mango seed weevil prevented development to the adult stage. A dosage of 20,000 r sterilized the adult weevils.

Indications are that a radiation dosage of 10,000 to 15,000 r will give adequate security against the Hawaiian fruit fly and mango seed weevil, without harming most fresh fruits and vegetables. Tests with this method under quasi-commercial conditions are now desirable.

Plans: The fruit fly research will be continued on essentially the same basis as heretofore in both Hawaii and Mexico but with increasing attention to population control with sterilization techniques involving both chemical sterilants and gamma radiation. The Western Pacific tests of the sterile fly release and male annihilation eradication methods will dominate the work of the Hawaii station. The search for effective lures and their evaluation as direct control agents are basic requirements that will require continued strong effort. Commodity treatment studies will be concerned further with streamlining application and other procedures and investigations of quarantine uses for irradiation treatments. The biology, behavior and host research is of continuing importance. With the growing frequency in fruit fly emergencies in the last dozen years, our resource of information on these serious pests cannot become too strong.

Publications: Treatments to Permit Movement of Agricultural Products under Plant Quarantine. Henry H. Richardson and J. W. Balock, Agric. Chemicals, 14 (2):27-29, 95, 97, 100. 14(3):43,45-46, 119, 121. 1959.

New Synthetic Lures for the Male Melon Fly. Morton Beroza, B. A. Alexander, L. F. Steiner, W. C. Mitchell, and Doris H. Miyashita, SCIENCE 131: (3046) 1044-1045. 1960.

Susceptibility of Life Stages of the Mexican Fruit Fly to Fumigation with Ethylene Chlorobromide. C. A. Benschoter. Jour. Econ. Ent. 53:(2), 323-325. 1960.

10. CHEMICAL CONTROL OF CITRUS INSECTS AND MITES

ENT

Problem: Effective and economical insecticides that will not leave objectionable residues on the fruit or in citrus by-products are needed for better control of citrus insects and mites, especially those species which have developed resistance to insecticides. Materials used in citrus orchards must interfere as little as possible with the activities of biological control agents.

Program: Insecticide research is carried on at Orlando and Lake Alfred, Florida and Whittier, California in cooperation with the respective State Experiment Stations. About $3\frac{1}{2}$ professional man-years annually have been devoted to this work. Anticipations are that an additional professional entomologist can soon be assigned to the Orlando station.

Progress: Demeton and Ovex resistant citrus red mites continued to lose resistance when reared in the laboratory without further treatment, but at an increasingly slower rate. After about 50 generations without treatment, the demeton mites were still 35 times as resistant as the susceptible strain. Resistance to Tedion, one of the new materials, has developed rapidly under field conditions. With its strong ability to develop resistance to new chemicals, the citrus red mite continues to be the most serious pest of citrus in California. In Florida none of several new materials and combinations of materials, which included kepone, toxaphene, dimethoate, ethion, trithion, and GC-5381 were as good as presently recommended treatments against the citrus red mite, Texas mite, and citrus rust mite on Valencia oranges.

Dimethoate was considerably more effective than parathion against California red scales located on fruit but less effective initially against infestation on the wood. After a period of time, control of the scales on wood with dimethoate was at least equal to that

obtained with parathion, presumably because of residual effectiveness against young scales. Dimethoate alone or in combination with parathion is considered to have unusual promise for red scale control. A strain of the California red scale sprayed with parathion in four laboratory generations was only slightly more difficult to kill than an untreated strain.

The use of chemicals to sterilize field populations of mites, scales, and other insects is a promising new line of attack currently under investigation. Several candidate materials applied to laboratory colonies of the citrus red mite in California affected reproduction. In one experiment, all of the offspring were males, indicating a total sterility effect since only unfertilized eggs produce males.

Plans: The research in California will be continued at about its present level. In Florida, increased emphasis will be assigned to laboratory and preliminary field evaluations of new insecticides and treatments, with special attention to selective properties. Facilities are now being developed at Orlando for an intensive investigation of chemical sterilants, antimetabolites, hormones and other agents that may upset reproductive or developmental processes in citrus insects and mites.

Recently all citrus insect research was consolidated under a single field investigations leader. The work now being carried on at Whittier, California will be transferred to the Campus of the University of California at Riverside, as soon as a laboratory building, now under construction, is completed.

Publications: Citrus Red Mites Resistant to Demeton and Ovex and Their Response to Tedion and Kelthane. F. Munger, J. E. Gilmore, and A. W. Cressman. Jour. Econ. Ent. 53(3):384-388, 1960.

Testing New Chemicals on Red Scale. A. W. Cressman. Calif. Citrograph 45(2):61, 63, 1959.

11. BIOLOGICAL CONTROL OF CITRUS INSECTS AND MITES

ENT

Problem: Concern over residue and resistance problems has emphasized the need for more attention to biological control and other means of suppressing citrus pests that may eliminate or curtail insecticide usage. Supplementation of the present beneficial parasite, predator and disease complex with additional introduced species and development of selective insecticides that will interfere least with the work of natural enemies are phases of this work requiring more intensive study.

Program: This continuing long-range program is being conducted in cooperation with the Florida Citrus Experiment Station at Lake Alfred and Orlando, Fla., and at Whittier, California. Approximately 2 professional employees are assigned to this work annually.

Progress: Basic studies in Florida citrus orchards have shown that some pests are kept under rather good control by natural enemies while others are not. A recently established parasitic wasp, Aphytis lepidosaphes, appears to have reduced the purple scale to minor pest importance. There is hope that remaining gaps in our biological control armament may some day be filled effectively, and that the goal of citrus production without extensive use of insecticidal sprays may be realized. Common insecticides, miticides, fungicides and nutritional materials applied to citrus in Florida varied widely in their effects on parasites and predators. Zinc and summer oil emulsions, which eliminate mites, were the most promising selective materials for use in an integrated program.

Laboratory methods for mass-culturing the citrus red mite virus in living mites were developed. The problem of storage and accumulation of stocks needed for field tests has not been entirely solved, but the recent finding that glycerine prevents injury caused by freezing has been of interest. An experimentally induced field infection disappeared during hot summer months. Another, in a grove subjected to less extreme summer temperatures has persisted since 1958, and there have been no damaging mite infestations. The virus disease sometimes occurred in heavily infested untreated groves. Suspensions of the virus were inactivated by exposure to sunlight and drying but natural residues remained infective for at least 8 days after all mites were removed. Other studies demonstrated that the virus must be ingested to start infection and is not transmitted through the egg. A dilution of one part of ground diseased mites in 400,000 parts water was infective. A promising method for starting field infections was the introduction of recently inoculated living mites. Single active diseased mites added to laboratory colonies were able to produce infection.

Plans: The basic investigations of natural enemies of citrus pests, and their more effective utilization and integration with other control practices, will receive continued and increased attention. In California, emphasis will be placed on the work with the citrus red mite virus, and its evaluation in practical field tests. Plans for surveys and explorations in foreign areas to find additional beneficial parasite species that may be needed to supplement the work of the present biological control complex are currently being developed.

Publications: Purple Scale Parasite Found in Florida. D. W. Clancy, and Martin H. Muma. Jour. Econ. Ent., 1959, 52(5): 1025.

A Disease of Citrus Red Mites. F. Munger, J. E. Gilmore and W. S. Davis. 1959, California Citrograph, Vol. 44(6): 190, 216.

A Suspected Virus Disease of the Citrus Red Mite Panonychus citri (McG.). Kenneth M. Smith, G. J. Hills, F. Munger and J. E. Gilmore. 1959, NATURE 184:70.

12. INSECT VECTORS OF CITRUS VIRUS DISEASES

Problem: Information on insect vectors is needed for a better understanding of the problems caused by citrus virus diseases such as tristeza, exocortis, and xyloporosis, and for development of sound disease control and regulatory procedures.

Program: This continuing program of basic and applied research on vectors of citrus virus diseases is being pursued at Orlando, Florida in cooperation with the Department's Crops Research Division, the Florida Agricultural Experiment Station and the Florida Plant Board. The vector studies involve about 1 man-year of Federal professional service annually.

Progress: Currently emphasis is being placed on development and improvement of techniques that will permit an accelerated study of the role played by aphids in the transmission of tristeza virus. Key lime seedlings are being tested in the hope they will provide a rapid means of obtaining symptom expression. An air-conditioned greenhouse, in which aphid transmission of tristeza has appeared to be more efficient than transmission under warm, outdoor summer temperatures, may improve test output. The possible existence of aphid strains having different transmission efficiencies, has been suggested by experiments with melon aphids from Belle Glade, Fla., which appear to be more efficient vectors of tristeza than Orlando aphids. Transmission tests with xyloporosis and exocortis viruses, involving aphids, a leafhopper, and a scale insect, have all been negative.

Plans: The citrus virus vector studies will be continued as formerly, and strengthened as far as additional facilities and improved methods will permit. The biology and control of known vectors, and factors that influence natural spread will receive continued investigation.

Publications: Symptoms of Cachexia in Orlando Tangelo, None in Sweet Lime and False Symptoms Associated with Purple Scale Infestations. T. J. Grant, G. R. Grimm, and Paul Norman. Plant Disease Reporter 43(12):1277-9. Dec. 15, 1959.

F. Mechanization of Production and Harvesting

13. MECHANICAL AIDS IN HARVESTING AND ORCHARD HANDLING

AE

Problem: A scarcity of hand labor coupled with the higher rates for a steadily increasing production of citrus fruit points up the need for the development and improvement of machines and methods that will reduce the amount of labor required and still maintain acceptable market quality.

Program: No formal program of research in this area has been initiated. At the request of the Agricultural Marketing Service and the Florida Agricultural Experiment Station assistance was given on some cooperative studies involving the harvesting and farm handling features of an across-the-board study of oranges, destined for the fresh market, from the field handling through the packing plants that involved a minor fraction of one professional Federal man-year.

Progress: Although most of the processing of oranges are handled in bulk, very little of the fresh fruit (30 million boxes in Florida) is handled in this manner because of the necessity of degreening. Early in Fiscal Year 1960 a cooperative research project was set up between this project, the Agricultural Marketing Service, USDA, and the Florida Agricultural Experiment Station to develop and evaluate methods and equipment for handling oranges destined for fresh market in pallet boxes. This project is responsible for the in-the-grove handling methods and equipment. Equipment and methods were tried which proved satisfactory under the heavy sand conditions and close tree spacing encountered in Florida citrus groves. Time studies on handling 221,400 pounds of oranges in pallet boxes showed that this method of handling reduces labor and container costs and results in a more efficient handling operation. Several growers in Florida are already adapting their operations to this handling system.

Plans: The research will be continued contingent upon the availability of funds and personnel in an effort to work out refinements in the overall handling operation, to try new equipment and improved combinations of equipment, and to obtain more detailed time and cost data so that specific recommendations can be made.

II. UTILIZATION RESEARCH

A. Chemical Composition and Physical Properties

.. CHEMICAL COMPOSITION AND PHYSICAL CHARACTERISTICS

SU, WU

Problem: Deterioration of the color and flavor of processed citrus and subtropical fruits is seriously limiting expansion of this processing industry. Because of higher production costs, this situation is resulting in decreased returns to growers. Knowledge of the chemical composition of these products is required for the development of improved processing procedures that will result in more stable products.

Program: A continuing long-term program of basic composition studies of citrus and subtropical fruits is carried on at WU's Pasadena and Albany Laboratories in cooperation with the Lemon Products Technical Committee, the Date Administrative Committee, the industry, California Experiment Stations and California Institute of Technology; and at SU's Winter Haven, Florida and Weslaco, Texas laboratories in cooperation with the industry, the Texas and Florida Experiment Stations and the California Institute of Technology; and involving 14 Federal professional man years and 3 professional industry-sponsored man years. Research on microbial flora in citrus fruits and olives is being conducted in Rehovot, Israel under P. L. 480.

Progress: Lemon Oil Composition: During the past year the origin of the "cymie" off-flavor in deteriorated lemon oil has been discovered at WU. Para-cymene, reported to be responsible for this off-flavor, has been isolated and identified. Fresh samples of lemon oil were found to contain less than 0.1% para-cymene, whereas badly deteriorated oils contained 7 to 8 percent. Para-cymene also was found in lime and tangerine oils but only in trace amounts in orange and grapefruit oil. Basic studies demonstrated that this para-cymene evolves from gamma-terpinene, an unsaturated hydrocarbon. It was previously considered that para-cymene resulted from breakdown of citral, the main aroma component of lemon oil. This new finding explains the failure of previous attempts to stabilize lemon oil and suggests new approaches to the problem.

Two aldehydes heretofore unreported in lemon oil have been identified, namely, n-heptanal and n-hexanal. The presence of small amounts of cintronellal was also confirmed. Fifteen aldehydes have now been identified in lemon oil. A quantitative gas chromatographic method of analysis was developed for determining the relative concentrations of the major aldehydes in citrus oils.

In recent years it has become increasingly difficult to prepare lemon oils that pass the U. S. Pharmacopoeia test for waxes. Infrared spectra of wax found in lemon oil were found to be virtually identical with those of a commercial wax (a coumarone-indene polymer) used to coat citrus fruits intended for fresh markets. While presence of this resin presumably does not constitute a health hazard, it has caused problems in obtaining oils that meet U.S.P. requirements. Oils high in this resin material are difficult to handle in conventional folding processes. This observation may result in changes in packing house procedures for storing and sorting lemons for fresh market and for processing. It will thus be possible to eliminate this problem and avoid thousands of dollars in losses in unsaleable products.

Volatile Flavor Constituents of Oranges: Orange flavor investigations have recently been initiated at the Albany Laboratory of WU as one of the major phases of the program on investigations on the drying of fruit concentrates using the newly developed foam-mat drying procedure. Knowledge of the flavor components is requisite to the development of high-quality fruit powders. The methodology and techniques developed in our long-term studies of strawberry oil are now being applied to the investigation on orange flavor.

The presence of alpha-pinene in orange oil was established by infrared and mass spectra, and nuclear magnetic resonance data. Although the hydrocarbons may not be important contributors to the desirable orange aroma, there are indications that some may contribute to the unpleasant aroma of oxidized oils. Further work is necessary to confirm this possibility.

The oxygenated compounds, easily separable from the hydrocarbons, can be separated into three groups. One of these has a very pleasant orange aroma. This material seems to be relatively stable to exposure to the atmosphere at room temperature. Work is now under way to isolate the compound or group of compounds which contribute to this aroma.

Hexa- and heptamethoxyflavones have been isolated and identified. This constitutes verification of unpublished work done at the Western Division's Pasadena laboratory.

Flavonoid Constituents in Citrus: For many years citrus processors have attempted to correlate the bitterness of processed grapefruit juice with the Davis colorimetric test for flavanones. During the past year studies at WU have shown the limitations of this test. It has been shown in other laboratories that naringin,

the main bitter constituent of grapefruit, on treatment with the enzyme naringinase loses rhamnose to form the nonbitter prunin and then loses glucose, forming naringenin. We have shown that prunin absorbs light at the same wave length as does naringin, so a positive Davis test would indicate the presence of the bitter naringin, whereas only the non-bitter prunin is present. Another component, poncirin, has also been isolated from grapefruit and its structure proven. This compound is bitter and does not give the colorimetric test.

Work has been started on the isolation and identification of the flavonoid compounds in Valencia orange peel. Two noncrystalline but chromatographically homogeneous flavanone glycosides have been isolated. One of these is isomeric with but different from naringin, the bitter glycoside of grapefruit, while the other is isomeric with but different from poncirin, the other bitter glycoside in grapefruit peel. Since neither of the flavanones of orange peel is bitter, it is tentatively concluded that the disaccharide portions of these compounds are rutinose derivatives rather than neohesperidose derivatives as found in grapefruit. These results differ from those reported in the literature and further work is planned to clear up this discrepancy.

Spectral evidence has also been obtained for the presence of an apigenin glycoside in orange peel (one of these was found earlier in lemon peel). Sinapic acid has also been isolated and identified.

Pharmacological Studies on Citrus Flavonoids: Studies at WU on the metabolic fate of flavonoids have revealed that 3,4,5-trihydroxybenzoic (gallic) acid when fed to rats and rabbits is detoxified by O-methylation of the number 4 hydroxyl group. These findings suggest that our basic metabolic research studies should be extended to other food and feed constituents which might be aromatized in the animal body.

Polyphenolic Constituents of Dates: The demonstration of enzymatic browning as a major route of darkening in dates at WU has resulted in increased emphasis on identification of the polyphenolic constituents. Analysis of the date extract has revealed the presence of two flavonol glycosides and two chlorogenic acids previously unreported in dates. An additional flavonol glycoside has been isolated but has not yet been identified. A third chlorogenic acid isomer has also been found in dates. Tests have shown that the chlorogenic acids but not the flavonol glycosides are substrates for the date-browning enzymes.

Data obtained on the deterioration of dates at 83° F. have been combined with data obtained previously on the effects of holding dates at 100° and 120° F. These results allow the apparent activation energies of the deteriorative reactions, enzymatic darkening, nonenzymatic darkening and enzymatic sucrose hydrolysis to be calculated. These reactions have energies of 22.1, 35.4, and 26.0 kilocalories per mole, respectively. The large energy difference between enzymatic and nonenzymatic darkening in view of their approximately equal rates at 83° F. explains why enzymatic darkening predominates below 83° F. and why nonenzymatic darkening predominates above that temperature. For example, at 65° F., nonenzymatic darkening will be 7.7 times slower than at 83° F. while enzymatic darkening will be only 3.6 times slower. Since enzymatic darkening can be prevented by either heat treatment or storage in inert gas atmospheres, over-all darkening under these conditions will be 7.7 times slower at 65° F. than at 83° F.

Microbial Flora in Fruits: Fundamental studies are being conducted on the microbial flora within the tissues of citrus, subtropical and deciduous fruits, and vegetables, and their effects on processing and preservation, as a basis for the development of products of superior quality. This research is underway in the Department of Food Technology, Agricultural Research Station, Ministry of Agriculture, Rehovot, Israel. The objective of this investigation is to identify the microorganisms within the intact tissues of fresh fruits, and determine their fate in conventional processes for preservation, such as brining and fermentation.

Shamouti and Baladi oranges, and Marsh seedless grapefruit have been under investigation in these early phases of this research. In one experiment, a total of 180 individual fruits were harvested and analyzed on the same day. Bacilli grew in the juice of just 1 Shamouti orange, while the juice of all the other fruits remained sterile.

Seeds were dissected from these same fruits and plated on yeast-dextrose-agar after crushing or freezing for 24 hours at -12° C. Bacteria developed from 12 out of 169 grapefruit seeds, 6 out of 42 Shamouti orange seeds and 26 out of 186 Baladi seeds.

When 105 oranges on the trees were surface infected by swabbing Pseudomonas on the stem end of the fruit, no bacteria could be recovered in 7, 14, or 28 days. The same result was obtained when the bacteria were injected into the fruit stem while the fruit was on the tree. When Pseudomonas was injected directly into the fruit, however, the bacteria was recovered in 13 out of 15 oranges within up to 28 days.

In limited studies on olives, slices were prepared from 3 varieties of 288 surface sterilized mature olives after discarding the section near the stem. Bacteria grew in 26 samples and fungi in 6. Parallel controls with autoclaved olives remained sterile.

Carotenoid pigments of grapefruit. It was previously reported that mevalonic acid, known to be a precursor of carotenoids, is first converted into a 20-carbon carotene intermediate. Continued work by the Weslaco Laboratory, in cooperation with the California Institute of Technology, to determine how the intermediate is converted into carotenoids has indicated that phytoene, formerly thought to be a precursor of carotene, is not involved. Experiments showed that, when radioactive mevalonic acid is supplied to tomatoes as a working tool for accelerated carotenoid synthesis, all petroleum-soluble radioactivity occurs in the cell chromoplasts. In other words, these subcellular components are the sites of carotenoid synthesis. Such synthesis in isolated chromoplasts has been demonstrated. Several preparations of chromoplasts from tomatoes have been obtained that accomplished a 10% to 12% increase in carotenes during a six-hour incubation period. No incorporation of labelled mevalonic acid occurred, however. This would indicate that possibly the final assembly of the carotenes occurs in the chromoplasts but allows the possibility that some enzyme system not in the chromoplasts may be required for total synthesis from mevalonic acid. The finding that the chromoplasts are the final assembly site for carotenes is an important step toward the development of an in vitro system for carotene synthesis. When such a system is achieved, direct studies on the enzymology of carotene synthesis may be started.

Bitter constituents of orange peel. In continued progress, methods have been developed at the Winter Haven Laboratory for reliable determination, in peel juice and oils, of linalool and alpha-terpineol, previously identified as two important volatile bitter substances in orange peel. The practicability of the methods has been demonstrated by application to commercial plant products. Headway has been made in classifying the behavior of the other volatile and the non-volatile, bitter material. Flavonoids of orange peel juice, extracted by amyl alcohol, do not appear to account for much of the non-volatile bitterness. In continued effort to identify the specific constituents responsible for bitterness not accounted for by linalool, alpha-terpineol, or crystallizable flavonoids, an extremely bitter concentrate has been obtained by benzene extraction of peel juice, and has been partially separated into crude fractions.

Bitterness of grapefruit juice. Progress has been made at the Weslaco Laboratory toward development of a method for objectively measuring the bitterness of grapefruit juice, by devising means of

correcting for the still unknown substances which impair the reliability of the presently used test for naringin, the principal bitter constituent. The ultimate goal is a practical routine test for measuring the degree of bitterness in fruit at different stages of maturity.

Oxidized flavors in citrus products. In continued investigations at the Winter Haven Laboratory evidence has been obtained to make certain aldehydes suspect as the causative agents of off-flavors variously designated as "oxidized flavors," "cardboard off flavor," "castor oil flavor," and the like. However, the responsible constituents are present in such minute concentrations that efforts to recover, isolate, and identify them by existing techniques have so far been futile.

Soluble solids in juices and concentrates. At the Winter Haven Laboratory, laboratory work and interpretative analysis of the compiled data were completed in an extended investigation of the determination of soluble solids in citrus juices and concentrates and improving the reliability of refractometric and densimetric methods for estimating the solids of input fruit and intermediate and final juice products.

In the first phase of the study, the effects of non-sucrose components on refractometer sugar scale values were determined. Citric acid and reducing sugars had been found by other investigators to require plus corrections. In this work, five other components were found to require negative corrections; and the aggregate of these negative corrections exceeded the positive corrections for citric acid and reducing sugars, at least in low-acid products such as orange juice and concentrate

In the second phase of investigation, analyses were made for the components of a series of commercial and experimental juice concentrates and the corrections for each component were applied to the refractometer value of each concentrate. Application of the sum of corrections for 7 nonsucrose components gave refractometric values for 4-fold concentrated orange juices that averaged only 0.25% higher than true soluble solids as determined by vacuum drying. Such results are a distinct improvement over the current practice of correcting for citric acid only, which gives results averaging 1.51% too high. With concentrated grapefruit juices, the difference for corrected refractometer values averaged only 0.04% too high, as compared with 0.91% for the currently used method. This multiple correction method, however, is hardly practical for routine use, because of the many analyses required to permit correction for each component of each sample.

In the final phase of study, simple empirical factors were developed for converting refractometer values, and also hydrometer and pycnometer values, to soluble solids. These factors are the average ratios, for single-strength and for concentrated citrus juices, of the soluble solids contents, as determined by vacuum drying, to the observed sugar scale values as determined by refractometer, hydrometer, and pycnometer. Use of the factors would result in improved accuracy and little, if any, loss in precision over correcting refractometer values for citric acid only or for all 7 components of citrus juices, present in sufficient quantities to affect adversely refractometer sugar scale values.

Plans: Continued work at SU laboratories on grapefruit carotenoids will include investigation of the morphological changes in chloroplasts and chromoplasts associated with color disappearance; exploration of the possibility of developing an in vitro system for studying the mechanism of carotene formation; and following up other leads uncovered by the investigations to date.

Further study of bitter constituents of orange peel will seek to purify and identify the specific components in the bitter concentrates previously obtained.

Continuous effort on citrus oxidized flavors will attempt sufficient refinement of sensitive techniques to identify the constituents responsible for the off-flavors.

Work at WU on lemon oil will be continued at the same level of activity. The recently initiated studies on flavor of oranges are now being conducted at an activity level of 2 professional man-years, and this degree of effort will be continued. Further work on the chemistry of flavonoids will emphasize studies of bitterness of Navel oranges, an increasing problem as large acreages are being planted in this crop. Pharmacological studies on the flavonoids of citrus will be continued. Research on dates will be continued at the present level of activity. The studies, under P. L. 480, of microbial flora in citrus fruits and olives will be continued.

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B. New and Improved Food Products and Processing Technology

2. NEW PRODUCTS FROM CITRUS AND SUBTROPICAL FRUITS

WU, SU

Problem: Expansion of markets for citrus and subtropical fruits is limited by the lack of diversity of use of these commodities. For example, dates are at present used almost exclusively in a limited number of baked products, and increasing land values and labor costs are threatening the very existence of the date-growing industry. Development of new food products will help to alleviate serious problems facing the date and other fruit industries.

A truly satisfactory dehydrated citrus juice product, which retails unimpaired quality in storage at ambient temperatures, and further retains fresh juice characteristics on reconstitution, would open up a large segment of consumption not accessible to frozen concentrated juices and provide a profitable outlet for a substantially larger volume of citrus fruit.

Program: Applied research on the development of new date products is carried on at the Pasadena Laboratory in cooperation with the

Date Administrative Committee of Indio, California involving 1 professional industry-sponsored man-year per year. Studies on the foam-mat drying of fruit are being conducted at the Albany Laboratory and involves 2 professional Federal man-years per year.

A continuing program of at least three years duration is carried on at SU's Winter Haven, Florida Laboratory in cooperation with WU and the Florida Citrus Commission, and involves approximately three professional Federal man-years annually.

Progress: New Date Products: Date pieces have been prepared for incorporation into breakfast cereal flakes. A novel approach is being used in an attempt to solve the problem of moisture transfer between the fruit and cereal flakes which results in soggy flakes. This approach involves modification of the date constituents (inversion of sugar) to produce a soft-textured piece having a moisture content (relative humidity) equivalent to that of the cereal flakes. Preliminary laboratory scale experiments have been encouraging.

Foam-Mat Drying of Fruit and Juices. Methods for making fruit and vegetable powders have been under study at the Albany Laboratory for several years. A recent development is foam-mat drying which offers advantages over other available methods and is being studied intensively with a view to putting it on a practical production basis.

In the original trials of foam-mat drying, the foams were spread on a Teflon-or-Mylar-coated belt in 1/8" layers and conveyed through a warm air stream. Most foods required about 60 minutes in 160° F. air to dry to 2% moisture. Under these conditions air velocity and humidity had an appreciable effect on the time required. The limit of the process was the transport of water within the product to the free surface at which it could evaporate. Therefore, steps were taken to reduce the mean distance to the evaporative surfaces.

The foam was next extruded in 1/16" to 1/8" diameter spaghetti-like strips onto the belt. Drying rate was augmented by heaters under the plate supporting the belt. These changes reduced drying time to about 15 minutes. The dry product was difficult to remove from the belt in some cases and it was not possible to load the belt very heavily. Nevertheless this form of dryer was shown to be satisfactory for sample preparation and is still in use at the Albany, California laboratory. About a tenth of a pound per hour of product can be expected from each square foot of active belt surface used.

A new development in foam-mat drying is called the "crater" technique. This involves extruding a thin layer of foam onto a perforated metal sheet. When the sheet is passed over an air jet, this foamed layer is pierced but not blown off. When heated air

is forced through the sheet from the clean side the foam is rapidly dried because of its extended surface in the direction of air movement. By this new crater technique the product containing 2% moisture can be doctored off the trays and the trays reused without cleaning.

The successful production of high-quality, instantly dispersible, tomato powders from foamed tomato juice concentrate and tomato paste has been extended to cover the drying of various fruit products. Orange, grape, and pineapple concentrates; apricot, prune, and apple purees; and various other liquid-form, fruit-containing mixtures have been dried by this method. Foam stabilizers used have included solubilized soya protein, albumin, sucrose fatty acid ester and glycerol monostearate. The most versatile stabilizer, glycerol monostearate (GMS), is particularly dependent on proper dispersion. Several effective methods of dispersion have been found. For most products, 1% stabilizer on the dry basis is enough. If the liquid has a low consistency and especially if it contains no fine solids, relatively more stabilizer is needed.

A cooperative agreement under a Memorandum of Understanding has been entered into by the Florida Citrus Commission and the Department through its Southern and Western Divisions to initiate a program to develop the foam-mat drying process for the manufacture of citrus juice powders. This program is being conducted at the Winter Haven, Florida Laboratory of the Southern Division under the supervision of scientists of the Western and Southern Divisions. During the past year, foam-mat drying equipment and related facilities designed by WU and financed by the Florida Citrus Commission have been installed in the pilot plant and preliminary "shakedown" runs made; laboratory control procedures have been set up and personnel trained in the operating techniques. General processing, raw materials and product variables are being investigated as they relate to yield, color, flavor stability, density and other quality characteristics.

Plans: Further studies at WU are planned on inverting the sugar in dates to produce soft-textured date pieces of low equilibrium relative humidity suitable for addition to cereal flakes. The reassignment of a professional food technologist will speed progress in this area. Cooperative research on the foam-mat drying of citrus fruits will be continued, supplemented by research on flavor of citrus oils and methods of locking-in of the flavor. An additional man is being assigned full-time to research on locking-in of flavor.

At SU, full scale pilot-plant evaluation of foam-mat drying for concentrated citrus juices will be pushed.

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3. PROCESSING FACTORS AFFECTING QUALITY OF PRODUCT

WU

Problem: Information is lacking on processing procedures that will yield more stable, fresh fruit-flavored citrus products. Most of the processing research aimed at increasing the stability of citrus products has been expended on frozen concentrate, with particular emphasis on improving the stability of this product. Very little research has been done on improved processing procedures that will enhance the flavor stability of both frozen and unfrozen citrus products.

Program: A continuing long-term program of research on processing of citrus products is carried on at the Pasadena Laboratory involving 1 professional Federal man-year per year.

Progress: Removal of "Cymie" Off-Flavors: The recent discovery that p-cymene evolves from gamma-terpinene in lemon oil is reported in the section of this report under chemical composition and physical properties. Since removal of gamma-terpinene from fresh lemon oil will obviate formation of "cymie" off-flavors, studies are being initiated on finding methods of accomplishing this removal. Treatment with permanganate, as well as other methods used by the essential oil industry, are being investigated.

Plans: Studies on the removal of the precursor of para-cymene from lemon oil will be continued.

4. FACTORS AFFECTING PROCESSING CHARACTERISTICS OF CITRUS

Problem: The processing industry is in need of more precise information on the effect of many factors such as rootstocks, and post-harvest treatment on the quality of the raw product for processing purposes.

Program: A continuing long term program of applied research carried on at Weslaco, Texas and Winter Haven, Florida, in cooperation with Crops Research of ARS, and the industry, and involving about 1 Federal professional man-year annually.

Progress: Effect of rootstock on red grapefruit. Final evaluation of the data (publication pending) from a four-season investigation in cooperation with the Citrus Rootstock Investigations, HCR, ARS, reveals that, for all practical purposes, fruit grown on Cleopatra mandarin, Red Blush grapefruit, citrumelo 4475, and Uvalde citrange rootstocks has quality equal to that produced on sour orange, the rootstock now in commercial use. Should it ever become necessary to abandon sour orange because of tristeza at least one of the foregoing rootstocks could become a satisfactory substitute.

Contamination of "color added" oranges with prohibited dye. A practical and fairly rapid procedure was developed, in cooperation with industry, for determination of prohibited Food Drug and Cosmetic (FD & C) Red 32 dye (carcinogenic suspect) in the presence of approved Citrus Red No. 2 on oranges. Some of the former was being detected on fruit colored with the latter. This not only violated U. S. regulations but also barred the oranges from export to Canada. With the technique devised the industry was able to trace the source of contamination to "pockets" in the dye application equipment not readily accessible for cleaning, and to correct the condition. Such a situation is important to processors as well as fresh-market shippers since packing house eliminations frequently go to the former for use in juice products.

Plans: Work on rootstocks and "color added" dyes has been completed. Renewed work on rootstocks may be necessary in the future to evaluate fruit produced on nucellar virus-free red grapefruit scions which have been grafted onto virus tolerant rootstocks as compared with intolerant rootstocks.

5. IMPROVED GRAPEFRUIT PRODUCTS

SU

Problem: New and improved grapefruit products of high consumer appeal and acceptance in respect to appearance, flavor, and stability are needed to provide new and increased outlets for the fruit and to increase economic return to growers.

Program: A continuing program involving fundamental and applied research in the laboratory, pilot plant, and processing plants in cooperation with the industry and the State Experiment Stations of Texas and Florida, in USDA laboratories at Weslaco, Texas and Winter Haven, Florida, and involving about three Federal professional man-years annually.

Progress: Canned juices from late season grapefruit. As reported last year, the following packs of canned single strength grapefruit juice were prepared from late season fruit for consumer preference tests by the AMS Market Surveys Section: (1) Plain juice from white fruit; (2) same fortified with added pulp from white fruit; (3) plain juice from Ruby Red grapefruit (weak color); and (4) same as (3), fortified with added pulp from early red fruit to enhance color.

The results of the tests, conducted with a panel of consumer households in a midwestern market, are reported in AMS Marketing Research Report No. 398, May, 1960, entitled "Consumer Preferences Among Pulp-Fortified and Unfortified Grapefruit Juices from Red and White Fruit."

Pulp-fortified frozen concentrated red grapefruit juice. In a series of preliminary experiments, several packs of frozen concentrated red grapefruit juice were prepared by the "normal" low temperature (74-80° F.) vacuum concentration procedure and cutting back the initial concentrate with red juice of high pulp content. Both the juice for concentration and the high-pulp cutback juice were obtained in a commercial plant. Among the variables investigated were fruit maturity (dates of processing, December through March), and temperatures of pasteurization of both juice and pulp (none, 155°, 160°, and 165° F.). Periodic examination of the packs held in frozen storage at 0 to 5° F. is still in progress. Preliminary observations indicated the high-pulp cutback improves the color of the concentrates, although visual examination of the reconstituted juices at the end of the processing season revealed considerable variation in color. This variation was apparently due to admixture, at the commercial plant where the juices originated, of white and pink fruit with the red fruit used for preparation of the juice and pulp; to variations in pulp content (9.5 to 19%); and to variations in the color of the high-pulp juice used for cutback on the different processing dates.

In some packs progressively higher heat treatments produced concentrates with better cloud retention on reconstitution; while in others the treatments had no effect. It is likely that in some instances the plain and/or pulp-fortified raw juice from the cannery had started to deteriorate before the heat treatments could be applied in the

laboratory. For further work a small commercial extractor will be installed in the laboratory so that all phases of the experimental processing can be carried out under controlled conditions on fruit of uniform quality.

Chilled grapefruit juices from Texas fruit. As previously reported, work was completed last year on establishing the optimum temperatures for heat-treatment-stabilization and storage of chilled juice products from Texas grapefruit and oranges. The findings indicate that good quality chilled juices can be made from Texas citrus and that they will remain stable at 32° F. for as long as 4 weeks after heat treatments at 165° to 180° F. Considerable interest has developed on the part of a number of potential commercial exploiters of chilled juice products from Texas citrus fruit. Data obtained on solids and Brix-acid ratio of oranges during the investigation have also been of interest to Texas Citrus Mutual and other agencies as providing a basis for comparison of expected yields of juice and concentrate from different varieties of Texas oranges.

Plans: Continued work on grapefruit products will be concentrated on pulp-fortified frozen concentrated juice from red fruit, to determine the optimum processing conditions for manufacture of a product of consistently high quality and stability.

6. MICROBIOLOGY OF CITRUS PRODUCTS

SU

Problem: Spoilage due to microbial activity is a problem with all kinds of processed citrus products, but it is particularly acute with chilled juice and sections or salad mixtures where the product is stored above freezing temperatures. There is need for more information on the kinds and biochemical activities of microorganisms present in fresh fruit that develop during processing and in the distribution system.

Program: A continuing long-term program of basic and applied research on the microbiology of citrus products is carried on in SU's Winter Haven, Florida laboratory involving about one Federal professional man-year annually.

Progress: Microbiology of chilled citrus salads. In continued work at the Winter Haven Laboratory, experiments were conducted to follow the effects of 3 levels of pH and 4 levels of added benzoate preservative on the growth and survival of 4 species of known spoilage bacteria and 2 strains of unidentified yeasts in a simulated cover

sirup at 50° and 35° F. At the former temperature, in general, the growth and survival of both types of organisms decreased as the concentration of benzoate increased and the pH decreased. At 35° F. growth rates were so low that the experiments were discontinued after a single species (Leuconostoc dextranicum) had been studied. The population of this organism decreased at pH 3.5 even in the absence of benzoate and the rate of decrease accelerated when benzoate was added.

In another series of experiments the effects of 3 preservations at 2 concentration levels on the time-temperature tolerance of citrus sections at 3 different temperatures (50°, 40°, and 30° F.) are under investigation. The citrus salads were packed in a local commercial plant in jars into which the required sirup had been dispensed in the laboratory. Sub-lots were placed in storage at the temperatures indicated; and controls for taste testing were transferred to tin cans and stored at -4° F.

Periodic taste panel evaluation of the samples stored at 50° and 40° have been completed. All the 50° samples were off flavor after one week. Samples stored at 40° F. and containing cover sirups which had originally contained 0.033% benzoate, sorbate, or a 1:1 mixture of the two were found to be off flavor in 5 weeks. The control without preservative and the samples with preservatives at a level of 0.066% were judged off flavor at 6 weeks. Samples stored at 30° F. are not off flavor after 10 weeks. All samples were tasted by the triangular technique against samples of the same initial composition which had been stored at -4° F. Chemical investigations are still incomplete and the microbiological data have not yet been correlated with the organoleptic or chemical data.

The findings to date indicate that maintenance of low storage temperature is of far greater significance for preservation of quality than is the addition of a small amount of allowable preservatives at the levels commonly used commercially. The temperatures cover the range observed in retail displays. Incomplete microbiological data indicate that microbial counts decrease at 30° F. and increase slowly at the higher temperatures.

Plans: In continued work the present experiments will be completed and new ones will be initiated to determine the influence of concentration and kind of preservative, and the pH of a simulated cover sirup, on the survival of pure cultures of representative citrus spoilage organisms. It may prove that the use of chemical preservatives to extend the shelf-life of chilled citrus sections is unnecessary or a lower concentration may be used.

7. TIME-TEMPERATURE TOLERANCE OF FROZEN CITRUS PRODUCTS

SU

Problem: Much of the poor quality of frozen citrus products experienced by the householder is probably due to improper temperatures encountered between the time it leaves the processor and is opened for use in the home. More information is needed on the effect of exposure to selected time-temperature patterns within ranges likely to be experienced during distribution and marketing on the residual storage life under household conditions (40° F.).

Program: A continuing program of basic and applied research on the factors affecting the storage life of frozen concentrated orange juice is carried on in SU's Winter Haven, Florida laboratory and in cooperation with citrus processors when commercial samples are used. About one Federal professional man-year annually is involved.

Progress: Frozen concentrated orange juice. During the year residual storage life tests at 40° F. were completed on all 12 of the commercially processed packs of frozen concentrated orange juice of the 1957-58 season which had been subjected to different storage temperature patterns. The tests demonstrated that the length of time 4-fold commercial concentrates will maintain cloud stability when held at household refrigerator temperature is reduced by storage at 5°, 10°, 15°, and 20° F., as compared with 0°. A previous observation that continuous storage produces the same effect as interrupted storage was confirmed. The 1957-58 laboratory-processed packs of 4-, 5 1/3-, and 6-fold concentrates made from juice heated at 150° F. are still under study. Their relative taste stabilities were reported previously.

Studies on the relative flavor stability and residual storage were completed on standard and high-density concentrates prepared in the laboratory during the 1958-59 season from commercial juice made with pulp washing. Taste-panel evaluation of 4-, 5 1/3-, and 6-fold concentrates stored at 40° F. as compared with 0° indicated that the flavor stability of the high density concentrates was lower than anticipated from past experience. The initial shelf life of the packs ranged from 0 to 2 days at 40° F. Upon frozen storage at 5°, 10°, 15°, and 20° F. these packs lost their residual shelf life. The low stability of the high-density concentrates in these tests suggests that modern commercial orange juice produced by the recently introduced practice of adding pulp washings may require heat treatment

even when high-density products are prepared. The commercial packs of 4-fold concentrate from the 1958-59 production are still under study.

Plans: Work will continue for at least another year to complete the studies on the commercial packs from the 1958-59 season and on the following material from 1959-60: 13 packs (11 orange, 1 tangerine, and 1 grapefruit) of commercial frozen 4-fold concentrates; 4 series of laboratory-processed packs of high-density concentrates made with and without heat treatment (1 series from pineapple oranges and 3 from Valencias); and 3 series of packs of laboratory-processed 4-fold concentrates each canned under nitrogen, vacuum, and air (1 series from pineapple oranges and 2 from Valencias).

III. MARKETING RESEARCH

A. Market Potentials, Preferences, and Development

1. CONSUMER PREFERENCES FOR GRAPEFRUIT JUICE

MD

Problem: Information on consumers' attitudes toward products and patterns of purchase and use, and reasons behind them is essential background material for efforts to maintain and expand markets. By providing data on preferences, buying behavior, intentions, attitudes, knowledge, habits, and opinions of new products or variations in product characteristics, consumer surveys assist the industry in planning effective marketing and promotional programs.

Program: National or local surveys among household and industrial consumers are undertaken from time to time. In some instances, the work is conducted in cooperation with land-grant colleges; contracts with private marketing research firms are used for national studies; smaller studies are usually handled by the Washington staff with the help of locally recruited personnel. During the past year, a study was completed using a panel of household consumers to establish relative preferences among different grapefruit juices. Less than one professional Federal man-year is utilized annually.

Progress: A panel of household consumers in Des Moines, Iowa rated pulp-fortified and unfortified juices from red and white varieties of Texas grapefruit to determine relative preferences among them. They indicated a slight preference for juice from the white rather than the red grapefruit. There was no evidence that fortification with pulp enhances or detracts from the appeal of either juice. Findings indicated that the red fortified juice is reasonably acceptable to consumers; therefore, prolonging the shelf life by fortification seems to be commercially feasible.

All the juices used in the experiment were relatively tart (Brix-acid ration of about 7.8) About one-fourth of the homemakers liked the tartness of each juice, but about half of them felt that all were too tart. It appears that a naturally sweeter or a sweetened juice might be more popular than the juices used in this test.

About 3 months after the completion of a promotional campaign for non-caloric artificially sweetened grapefruit juice, a probability sample of homemakers in Fort Wayne, Indiana was interviewed to determine use of and satisfaction with the test product. The survey showed that 40 percent of the homemakers were aware that

the test juice was available in local stores. Thirteen percent of the respondents had bought the product, and two-thirds of these users had made repeat purchases, some as many as four or more. Almost all users of the artificially sweetened grapefruit juice expressed complete satisfaction with the product. Most favorable comments referred to flavor. Only 1 user in 5 mentioned the non-caloric sweetener as a reason for satisfaction, however. Results of the retail store phase on marketing artificially sweetened grapefruit juice were made available to the committee a year ago.

About half the homemakers interviewed felt that the use of artificial sweeteners in food was generally acceptable, and none of those who had not used the test juice but were aware of its availability indicated that the artificial sweetener was a deterrent to its use.

Plans: A publication will be released this fiscal year covering all aspects of work relating to artificially sweetened grapefruit juice.

Publications: Consumer Preferences among Pulp-Fortified and Un-Fortified Grapefruit Juices from Red and White Fruit. J. Scott Hunter. Marketing Research Report 398, May 1960.

2. IMPROVED MERCHANDISING

MD

Problem: A continuing need exists to encourage improvements in the retail merchandising of citrus and subtropical fruit items to maintain a strong competitive position for such items in the marketplace and obtain maximum levels of purchase for all products.

Program: The program is one of long-term marketing research conducted on a national, regional, and local level depending on specific need. In most instances, research is conducted in retail food stores and involves close cooperation of store management. A study designed to determine consumer acceptance of "color added" and "natural color" fresh Florida oranges, was conducted in 15 retail food stores in Cleveland and 9 stores in Philadelphia during the latter part of 1959. Less than one professional Federal man-year annually is involved.

Progress: Results of the experiment in Cleveland indicated that sales of the natural color oranges were nearly 15 percent less than sales of the color added fruit when displayed separately. This is a ratio of 5 to 4 in favor of color added fruit. When the two types of fruit were displayed side by side, the color added fruit outsold the natural color by a ratio of 6 to 4. When both types

of Florida oranges were on display simultaneously instead of color added fruit only sales increased nearly a third without change in total display area.

In Philadelphia, sales were about equal for the two types of oranges tested when displayed alone or in combination. Also in the Philadelphia stores, total Florida orange sales increased when both types of fruit were displayed. Both color added and natural color fruit were excellent in quality; however, the difference in color between the two kinds of fruit was not large in either Philadelphia or Cleveland.

Point-of-purchase interviews were conducted in Cleveland and Philadelphia, with about 600 homemakers in each city who had bought fresh Florida oranges during the study. In each city, about 75 to 80 percent of the respondents knew color was sometimes added to oranges. Nearly half the buyers of natural color oranges in the two cities felt the addition of color was bad, while one-fourth of the color added purchasers held the same opinion. Regardless of type of Florida orange selected, about 4 of every 10 shoppers interviewed reported that it made no difference whether color was added.

Plans: Another phase of work on consumer acceptance of color added versus natural color in fresh oranges is planned. This is scheduled for the fall of 1960 and spring of 1961, if natural color oranges have a substantially greener external appearance than the color added fruit. Consumer surveys will be conducted among homemakers again if staff is available.

A study evaluating the extent of use of in-store promotional materials supplied by producer groups is scheduled for the fall of 1960. Observations will be made of materials used by type and size of store, department, etc. in a randomly selected national sample of 1,800 retail outlets having an annual sales volume of \$300,000 and over. In 10 metropolitan centers located in the different regions, interviews will also be held with personnel responsible for merchandising from headquarters down to the store level to ascertain policy relating to in-store promotional materials. Also certain types of wholesalers will be interviewed in each metropolitan center to determine their policy concerning the handling of in-store promotional materials.

Publications: Marketing Artificially Sweetened Grapefruit Juice. Michael G. Van Dress. Agricultural Marketing Vol. 5, No. 8, Aug. 1960.

Marketing Artificially Sweetened Grapefruit Juice. By Robert E. Frye, J. Scott Hunter, and Michael G. Van Dress. Marketing Research Report 432, September 1960.

3. EVALUATION OF PROMOTIONAL PROGRAMS FOR CITRUS FRUIT AND
FRUIT PRODUCTS

MD

Problem: Because of price depressing surpluses and low levels of consumption for a number of citrus fruits and fruit products, producer groups have turned to promotion in an effort to maintain and expand markets. To assist them in planning, initiating, or redirecting promotional activities to achieve maximum impact on consumer demand, these groups need information on the most appropriate procedures to use in developing and carrying out promotions; the effectiveness of alternative types of promotion; and the nature and extent of promotional programs conducted by other fruit producer groups.

Program: A continuing long-term program of marketing research is conducted on a national, regional, or local scale and in cooperation with State Departments of Agriculture, colleges, agricultural producer promotional groups, fruit processors and distributors. A contract was made with Northwestern University to develop a manual of basic advertising and promotional procedures. It involves less than one professional man-year annually and some contract funds.

Progress: Northwestern University has collected information for the development of a manual of basic advertising and promotional practices which will be of assistance to agricultural producer groups in planning and carrying out promotional programs. Information obtained through a survey of forms using advertising agencies and the advertising firms themselves included: (1) The organizational structure of advertisers, the responsibilities and functions of each department, and the influence of such factors as the size of advertising budget and the specific objective or emphasis of the promotional program on the types of organizational structure; (2) the advertiser-agency relationships and responsibilities in carrying out promotional programs; and (3) how advertising and public relation expenditures are allocated among the different services provided by the advertising agencies.

The effectiveness of a special promotional campaign sponsored by 22 Florida producers of frozen orange concentrate is being determined from data obtained under contract with the Market Research Corporation of America from their national consumer panel of households. Preliminary findings indicated that sales of frozen concentrated orange juice were increased significantly during the periods of advertising and promotion (September-March) and during

the immediate post promotion months (December 1959-March 1960). It is estimated that an average price reduction of approximately two cents per 6-ounce can below the prevailing price would have been necessary to obtain the monthly sales volume that was reported for September 1959-March 1960. A price reduction of this magnitude would have amounted to reduction in sales revenue of approximately \$18.2 million at retail during this period. The cost of the promotional program amounted to \$3.9 million.

A preliminary report entitled "Sales Effectiveness of a Special Promotional Campaign for Frozen Concentrated Orange Juice" is in process of review. The final report is anticipated at an early date. A report, "Basic Advertising and Promotional Procedures for Producer-Promotional Groups", is anticipated during 1961.

Plans: Further work is planned on measuring the effectiveness of advertising programs and special campaigns for citrus and selected citrus products.

4. PURCHASE AND DISTRIBUTION PATTERNS

MD

Problem: Production of oranges and grapefruit has partially recovered from effects of freezes in 1957-58, resulting in marked changes in price levels and shifts in utilization as between fresh and processed uses. Further, substantial increases in production appear to be in view. The proportion of families buying citrus products, however, is currently below prefreeze level. It is necessary to obtain continuing information on retail movement of citrus and competing products to provide a basis for increasing efficiency of marketing operations, and to obtain maximum returns to growers.

Program: This long-term continuing program provides for obtaining periodic data and publishing reports on the volume of consumer purchases of citrus and competing products, retail prices, size and frequency of purchase, and on characteristics of families buying. The Florida Citrus Commission, with some financial help from the California Prune Advisory Board, will cooperate through September 1961 by providing the contract cost of obtaining the basic data from the Market Research Corporation of America, a private research organization. The program requires about one professional Federal man-year annually.

Progress: Purchase data are regularly provided by a series of 4 different reports distributed to growers, processors, and distributors of citrus products, and to interested marketing, advertising and research agencies. Monthly reports provide current estimates of national purchases, prices paid, percentage of families buying, and size and frequency

of purchase of citrus and competing products. Total and per capita purchases by regions, and purchases by type of retail outlet were reported for the first quarter of 1960. The percentage of families buying, size of purchase per family, and per capita purchase rates were reported for April-September 1959 by geographic location and for such family characteristics as amount of family income, size of family, age and presence of children, occupation and education of family head, and age and employment status of housewife. The proportion of grocery stores that had citrus and competing products available for customers was reported for August 1959 and February 1960.

Consumer purchase data are of proven value in bargaining processes, and in describing the extensive shifts that have occurred in utilization of fruit in fresh and processed form, and of production of different products. They were also of great assistance in formulating the promotional program of processors in the fall of 1959 that greatly stimulated movement of frozen concentrated orange juice.

Plans: Reports on household purchases will be continued on a somewhat reduced basis beginning with October 1960. The report on availability by retail outlet, and reports on purchases of fresh oranges and fresh grapefruit will be discontinued as of September 1960. Reports by regions and retail outlets, except for prune juice, will also be discontinued as of that date. The Florida Citrus Commission with assistance from the California Prune Advisory Board will continue to supply the basic data, and the Department will continue to make the analyses and to publish and distribute reports.

Publications: Consumer Purchases of Selected Fruits and Juices. Clive E. Johnson. Monthly Consumer Purchases of Fruit Juices Series. (CPFJ)

Consumer Purchases of Selected Fruits and Juices by Regions and Retail Outlets. By Clive E. Johnson. Quarterly CPFJ series. CPFJ-87, June 1959; CPFJ-92, September 1959; CPFJ-101, March 1960.

Consumer Purchases of Selected Fruits and Juices by Family Characteristics. Clive E. Johnson. Annual CPFJ series. CPFJ-98, April-Sept. 1959.

Availability of Selected Fruits and Juices in Retail Food Stores. Robert E. Frye and Clive E. Johnson. CPFJ-91, August 1959, CPFJ-100, February 1960.

B. Measurement and Evaluation of Market Quality

5. OBJECTIVE MEASUREMENT OF MARKET QUALITY FACTORS

MQ

Problem: A wide divergence in quality exists among individual fruits and new methods and techniques are needed to upgrade fresh and processed citrus and other subtropical fruits by separating out those of low quality.

Program: A five-year continuing program is being carried out at Miami and Orlando, Florida and Beltsville, Maryland, involving about three professional Federal man-years annually. Other work has been conducted under contract with Industrial Electrical Engineers, North Hollywood, California for the development of an electric date moisture sorter. The Florida Avocado and Lime Commission, Florida Avocado Reserve Trust Fund and the Florida Agricultural Experiment Station cooperate in the program.

Progress: External and internal color as related to quality in oranges. Light transmission studies (horticultural spectrophotometer) on Pineapple and Valencia oranges show both the chlorophyll and carotenoid content to be related to solids, acids, and solids-to-acids ratio. The correlation is stronger in the midseason than in the late oranges since the chlorophyll content of earlier varieties more closely parallel maturity. Likewise, the linear relationship between chlorophyll, carotenoids and eating quality disappears late in the season. Reflectance measurements (Hunter color difference meter) are complicated by rind blemishes such as melanose or rust mite injuries which affect the readings. However, the instrument may be useful in grading and sorting fruits for blemishes.

Maturity of avocados. From June 1959 to March 1960 over 1,000 avocados, representing 6 important and 32 minor varieties, were studied. Studies included tests for oil content, specific gravity of flesh, palatability, diameter, softening time and weight loss during softening. As found in previous season's average oil content increased as the season progressed but variation among individual fruits was so great that it precluded the use of this method to determine maturity. Except for the Pollock variety, average specific gravity of flesh varied little from one sampling date to the next. A relationship was found between fruit maturity and days to soften as well as between maturity and weight loss during the softening process.

Maturity of mangos. The objective this year was to determine whether all mangos on the tree were ready for harvest at the time fruit with a color break was first observed. The stripping of Zill mangos from trees with fruit displaying a color break resulted

in numerous immature fruits which shrivelled and did not ripen satisfactorily. A similar stripping of Kent and Haden mangos several seasons ago resulted in satisfactory ripening of all fruits. A possible explanation of the difference in maturity among the varieties is two distinct and widely separated bloom dates with Zill mangos while Kent and Haden mangos had one primary bloom.

Maturity of Murcott Honey oranges. In fruit from trees on rough lemon rootstock soluble solids increased from December to March from 9.5 to 14.4 percent, titratable acidity decreased from 0.78 to 0.68 percent, and solids-to-acid ratio increased from 12.2 to 21.1. Taste ratings increased from 68 to 90, while ascorbic acid decreased from 24 to 14 mg. per 100 ml. of juice. Texture and rind color improved greatly in December and January. Sunburn and dryness were present in considerable amounts on young trees. Fruits from trees on sour orange rootstock were highest in solids, total acids, ascorbic acid and taste; however, they tended to dry out more late in the season than fruit from other rootstocks. Fruit on Cleopatra rootstock were the juiciest and had the highest average ratio. Tentative maturity standards were presented to the Florida Citrus Commission. The resulting regulation states that Murcotts shall be considered mature when the citric acid does not exceed one percent; or, if it does exceed one percent, that the solids-to-acid ratio must be 12-to-1 or greater. For processing they must meet orange standards (10-to-1 ratio).

Dates Research under contract has shown that a radio-frequency measurement gives the most satisfactory indication of the moisture content of dates. A laboratory-type instrument was constructed by the contractor. This instrument has been tested by members of the California Date Growers Association with favorable results, and the contractor is now constructing an automatic unit. The automatic unit will demonstrate the practicability of automatic sorting of dates for moisture content.

Plans: Research will continue on maturity measurements in Murcott Honey oranges, and on the major and some of the minor varieties of avocados. Emphasis will be placed on non-destructive methods of evaluating quality such as light transmission and reflectance instruments because of their possible usefulness in the automatic electronic sorting and grading of fruit.

The development of maturity measurements in mangos will be discontinued because of shortage of personnel.

Work on measuring moisture content of dates will be completed after construction of a demonstration machine by the contractor and tests for performance on the 1960 crop.

Publications: Evaluation of Indices for Florida Avocado Maturity. Thurman T. Hatton, Jr. and Carl W. Campbell. Proc. Fla. State Hort. Soc. 72:349-353, 1959.

The Importance and Early History of the Temple Orange. Paul L. Harding. Proc. Fla. State Hort. Soc. 72:93-96, 1959.

Variations in Quality of Marsh Grapefruit. William G. Long, Paul L. Harding, Mortimer J. Soule, Jr. and Milliard B. Sunday. AMS-336, Oct. 1959.

C. Product Protection During Marketing

6. POSTHARVEST PHYSIOLOGY AND STORAGE

MQ

Problem: Because of the expansion in acreage and production of citrus and other subtropical fruits, there is a need to extend the marketing season of these fruits and to separate strong and weak fruit as to keeping quality.

Program: The long-term continuing program calls for applied, basic and technical approaches to the problem. Part of the research is in cooperation with the Florida Agricultural Experiment Station. The work is conducted in Florida, Texas and California and involves about four professional Federal man-years annually.

Progress: Cause and prevention of rind breakdown. Rind breakdown was reduced in Pineapple and Valencia oranges stored at 32° and in Marsh grapefruit stored at 40° by treatment with polyethylene emulsion or water wax before storage. Brushing, either before or after treatment, with Dovicide-A + hexamine at near 120° F. produced symptoms somewhat similar to naturally occurring rind breakdown, especially when held at high humidities following treatment. Typical rind breakdown was not produced by extreme exposures to hot water, color-added dyes, air movement or low humidities.

Weight Loss during storage. No experimental work was done on this project during the year due to transfer of personnel and facilities to more urgent projects.

A report of past work has been completed. In this report data are summarized on the rate of weight loss by avocados, lemons, oranges, and grapefruit under specified conditions. Basically the rate at

which these commodities lost weight in storage varied with the vapor pressure deficit between product and surrounding air. The deficit varied with storage temperature and humidity differences and with temperature gradient between commodity and air.

Storage of Persian limes. The objective of this work is to determine the factors affecting the storage, shelf life and quality of limes on a seasonal basis. Newly set fruits from a March 1959 bloom were tagged on 6 trees in each of 3 groves. Diameter measurements were made on 50 fruits per tree at intervals throughout the development of the fruit. Composition and quality of the fruit were also determined at monthly intervals. For any given size of lime, there was little variation throughout the season in such characteristics as skin and flesh texture, juice content, color, solids and acids. At storage temperatures of 50° and 70° F., limes of 2 1/8 inches and larger retained a fresh turgid appearance better than smaller limes; however, more yellowing was apparent in the larger sizes. Limes of 2 1/8 inches and larger retained a fresh turgid appearance better than smaller limes; however, more yellowing was apparent in the larger sizes. Limes of 2 1/8 inches and larger had a higher percentage of juice. Limes smaller than 2 1/8 inches retained the green color longer than larger fruit but turned brown instead of yellow during ripening. Also they became hard and leathery, and became more so with decreased size. The findings provide information on quality after different periods of storage for each size of lime.

Storage and ripening of avocados and mangos. The objective of this work was to determine the storage and ripening response of leading Florida avocado and mango varieties.

Chilling injury occurred in avocados of the Fuchs and Pollock varieties after 3 days at 40° F., or 6 days at 45° and 50° F. Chilling injury was found in Waldin and Booth 8 avocados after 15 to 18 days at 50° F. Lula avocados showed no chilling injury after 25 days storage at 45° and 50° F.

Haden, Zill, Smith, Sensation and Keitt mangos stored at 50° F. softened in 2½ to 3 weeks. Mangos stored at 50° to 60° F. were of poor flavor due to incomplete conversion of starch to sugar, but when such fruits were held at 70° to 80° F. for 1 or 2 additional days they became sweet and palatable. Severe chilling injury occurred in mangos at 35° and 40°, even with brief periods of storage. Mangos stored at 45° F. for 1 week or more and subsequently ripened at 70° F. did not show visible chilling injury but tended to decay severely and were poor in flavor.

Rind breakdown and oil spotting of citrus. Florida Valencia oranges were subjected to stress conditions in an attempt to predict susceptibility to rind disorders. Fruit was immersed in hot water

alone, or in hot water containing color-add dyes at temperatures up to 145° F. for periods of from 5 to 30 minutes. At temperatures above 120° F. for more than 10 minutes the fruit had a cooked appearance but no symptoms of rind breakdown. Dehumidified air at temperatures up to 140° F. with a velocity of 1200 linear feet per minute produced a dried out appearance but no rind breakdown. Brushing, either before or after treatment with Dowicide-A + hexamine at temperatures near 120° F., produced symptoms somewhat similar to naturally occurring rind breakdown, especially when held at high humidities following treatment.

Texas studies were initiated to find the cause and control of rind-oil spotting (oleocellosis) in Marr's Early orange, a variety that some shippers refuse to handle because of this external spotting. Conditions which increase fruit turgor at picking time such as high relative humidity and high soil moisture increased susceptibility to rind-oil spotting. Conditions which decrease fruit turgor, especially low relative humidity with clear skies and high insolation, significantly decreased the occurrence of rind-oil spotting. Measurement of test oranges on the trees, taken at 10 a.m. and 2 p.m., showed a reduction in diameters in the afternoon if dry clear weather prevailed. No reduction in diameters occurred in afternoons during periods of heavy overcast skies, drizzle and rain. By picking only in the afternoons of clear, sunny days and by deferring picking after rain or irrigation for 2 to 3 days, rind-oil spotting can be practically eliminated. Shippers and growers were advised of the findings as the work progressed and have made use of them.

Controlled atmosphere storage. Studies were continued on extension of the storage life of Texas red grapefruit by modification of storage atmospheres. November harvested grapefruit were stored in controlled atmospheres up to 20 weeks at 50° F., 2.8-4.0 percent oxygen, and 1.2-3.8 percent carbon dioxide. The original greenish peel color, firm texture, and good flavor were maintained with no development of decay. Late-season fruit stored for only 10 weeks developed a high percentage of decay in the CA chambers. Twelve-week storage tests in which the relative humidity was controlled at 85 percent resulted in 9.5 percent weight loss and increased pitting, 5 to 10 times that which occurred at high humidities. Circulating air of 100 percent relative humidity resulted in a 4 percent weight loss as compared to 2 percent in static air. There was no increase in decay at the high humidities.

Lemons from different producing areas did not differ significantly in their response to controlled atmosphere storage or in their resistance to chilling injury. Lemons stored in an atmosphere of about 5 percent oxygen and 5 percent carbon dioxide seemed to be more tolerant of low temperature storage than those stored in air. Curing lemons at 58° F. did not improve their resistance to chilling injury when subsequently stored at 38° F., either in air or modified atmosphere.

Storage of late oranges. After 2 months storage at 32° F., Pope Summer oranges treated with Citrashine + Dowicide-A with hexamine or with polyethylene emulsion + Dowicide-A with hexamine showed decidedly less aging than similarly treated fruit held at 38° F. During the period at low temperature very little decay or pitting developed.

When these samples were held for one week at 70° F. after removal from storage, the fruit previously stored at 38° F. developed considerably more decay, aging and pitting than fruit stored at 32°. Prestorage treatments had relatively little effect on the amount of decay and pitting which developed at 70° in fruit previously stored at 32°. The prestorage treatment of Citrashine + Dowicide-A with hexamine controlled decay better during the holding period than the polyethylene + Dowicide-A with hexamine treatment in fruit that was stored at 38°.

Plans: Emphasis will be given to research on the physiology of citrus fruit and especially to the cause and prevention of rind breakdown. Methods for forecasting susceptibility to rind disorders and decay will also receive attention. The work will continue on the color changes and keeping quality of Persian limes, on the minimum and optimum storage conditions for avocados and mangos, and on the extension of marketability through controlled atmosphere storage for lemons, oranges and grapefruit. Studies on the ripening and storage of Florida mangos and avocados will be temporarily discontinued due to staff shortage. Investigations of the behavior in storage of desert lemons are completed.

Publications: Chilling Injury in Pollock Avocados During Cold Storage. Carl W. Campbell and Thurman T. Hatton, Jr. Proc. Fla. State Hort. Soc. 72:337-338, 1959.

Keeping Quality of Marsh Grapefruit after Nitrogen and Potash Fertilization. Paul L. Davis and Paul L. Harding. Proc. Fla. State Hort. Soc. 72:83-87. 1959.

The Reduction of Rind Breakdown of Marsh Grapefruit by Polyethylene Emulsion Treatments. Paul L. Davis and Paul L. Harding. Proc. Amer. Soc. Hort. Sci. 75: 271-274, 1960.

7. POSTHARVEST DISEASES

MQ

Problem: Loss from decay is an expensive item in the marketing of citrus and other subtropical fruits. It may occur at any stage of marketing and may be traceable to infection of fruit on the tree.

Program: A continuing long-term study of basic and applied research conducted at Orlando, Florida; Pomona, California; Chicago, Illinois and New York City, New York, and involving about three Federal professional man-years annually.

Progress: Inoculation studies on immature oranges on the tree. Inoculation studies with the stem-end rot organisms in the grove substantiated previous results in that spores of the casual organism could be placed on growing Hamlin oranges as early as June and produce decay after the fruits were harvested in November.

Control measures for Florida citrus. Studies made throughout the season have further substantiated the superiority of 2-propynyl-ol-carbanilate as a postharvest fungicide for citrus in comparison to standard fungicides when it is incorporated in a water wax emulsion at the rate of 0.75 to 1 percent. A chemical company is considering the feasibility of manufacturing this compound for use on citrus. Its toxicology is unknown.

Thirteen new compounds were screened for control of decay in oranges. None was sufficiently effective to warrant further testing. Inoculation studies with green mold have shown that susceptibility of oranges is affected by variety, maturity, and time of injury. Increased amounts of green mold during midseason (winter) is apparently due to more susceptible varieties. Hamlin and Pineapple varieties are the most susceptible to green mold decay while Valencia is the least susceptible. Susceptibility also increases with increase in maturity. The incidence of green mold in oranges is increased by hydrocooling in plain ice water. This increase occurs when hydrocooling is done either before or after artificial wounding and inoculation. Dowicide-A in the hydrocooling water significantly decreases decay, provided the application occurs after wounding.

Florida test shipments with hydrocooled oranges. Two rail shipping tests with oranges were conducted in late April and late May to New York. Decay on arrival and after 1 and 2 weeks at 70° F. was unusually low. Differences were slight between air-cooled and hydrocooled fruit. Although decay was light fungicides were beneficial. Rind breakdown was not appreciably affected by either method of precooling.

Hot water treatment for mangos. In limited experiments mangos infected with anthracnose caused by Colletotrichum gloesporioides were treated with hot water ranging from 122° to 185° F. at time intervals ranging from $\frac{1}{2}$ to 2 minutes. Mangos treated at 140° F. for 1 or 2 minutes and kept at 70° F. for 2 weeks showed little anthracnose development and no evident damage to the fruit. Mangos treated at higher temperatures showed injury while those treated at lower temperatures had a high incidence of anthracnose.

Decay of lemons and grove history. The incidence of natural infection encountered in lemons harvested with extreme care was correlated with the decay history in the orchard. The causal organisms were isolated much more consistently from orchards with high decay histories than from orchards with low decay histories. Lemons carefully harvested from the latter and held under commercial storage conditions showed very little decay after 49 days. Under the conditions tested, injuries, which may have occurred during washing and treating, did not significantly increase decay of the washed and treated lemons as compared with unwashed and untreated lemons.

These findings suggest that predisposition of lemons to natural or post-harvest infection may be intrinsic in certain lots of fruit and may account for so-called "weak" and "strong" lots of fruit.

Biphenyl resistance. Strains of Penicillium digitatum (green mold) were studied to evaluate the relative importance of biphenyl-resistance among strains of the fungus.

In a biphenyl atmosphere, the production of conidia in vitro was reduced in all of several hundred selected isolates held under controlled conditions. Prevention of conidial production in saturated or near-saturated biphenyl atmospheres depended on (a) the period of exposure, and (b) the ability of the isolate to produce spores. Tolerance to biphenyl (measured by the degree of sporulation after 120 hours exposure) varied from failure to produce conidia to sparse production of conidia. Failure of any test isolates to sporulate as heavily and as quickly as their respective controls was considered significant.

Some strains readily controlled in vitro were poorly or not at all controlled in inoculated lemons held in the presence of biphenyl sheets at 54° and 68° F. These observations and evidence that "high" concentrations of biphenyl suppress but do not necessarily prevent sporulation, suggest varying tolerances to the fungistat.

Effective use of biphenyl. This work was undertaken at the urgent request of the California citrus industry to learn how to improve on the effectiveness of biphenyl in the control of Penicillium rot and yet

stay within legal tolerances for biphenyl in the fruit. At 68° F. the biphenyl in the application sheets was about 50-90 percent depleted in 1 week. Depletion was more rapid in the upper than in the lower of the 2 sheets and more rapid in vented than in nonvented cartons.

Biphenyl depletion at 54° F. was less than half as fast as at 68°. Biphenyl accumulation in the fruit has been too variable to permit conclusions other than that it is higher in nonvented than in vented cartons and higher at 68° F. than at 54°.

Biphenyl concentrations prevailing in both vented and nonvented cartons of lemons with the usual commercial application of biphenyl have not controlled decay or sporulation in the strain of green mold organism used, even though practically complete prevention of sporulation was accomplished in vitro in an atmosphere approximately saturated with biphenyl at room temperature. This strain appears to be tolerant to moderate concentrations of biphenyl. Application of biphenyl treatment at the time of inoculating and 1 day after inoculating produced similar results.

Control by irradiation. Dose rate. Lemons. One explanation for the failure of gamma radiation to control decay of lemons in a commercial pack has been the inability to deliver a fast dose rate with present facilities. Results with irradiation of green mold infected lemons indicate that in the determination of dose requirements for decay reduction, the dose rate plays as important a role as does the total dose delivered. Within the range of 125,000-210,000 rads a fast gamma flux (12,000-23,000 rads/min.) delayed decay and resulted in a lower average infection score than a slow rate of flux (1200-2300 rads/min.). This same relationship between dose rate and decay control has not been demonstrated in trials with strawberries infected with Rhizopus stolonifer and Botrytis cinerea. There were no consistent differences in survival of citrus and strawberry fungi in culture when given similar dosages at the fast and slow rates of gamma flux.

Avocados. Waldin, Booth 8 and Lula varieties of avocados were irradiated at doses from 10,000 to 200,000 rads and evaluated after holding at room temperatures. There was delayed and abnormal ripening at doses from 25,000 rads to 200,000 rads and these responses were proportional to the dose. Doses of 100,000 and 200,000 rads induced moderate to severe vascular discoloration while skin injury (browning) was apparent in some cases at dosages as low as 25,000 to 50,000 rads.

Mangos. Hard-green mango fruit of the Cecil variety was irradiated at from 10,000 to 200,000 rads and evaluated at intervals during ripening for skin and flesh color changes and development of incipient

Anthrachnose (Colletotrichum gloeosporoides). Delay in ripening was evident at all doses tested and was especially pronounced at 200,000 rads and less so at 100,000 rads. Anthrachnose lesions developed on fruits treated at 10,000-50,000 rads as they ripened slowly. However, the lesions did not develop on fruits following treatment with 100,000 and 200,000 rads. The retardation of the disease appeared to be correlated with the greatly delayed ripening of the fruit at the high radiation doses. This is supporting evidence for the indirect influence of radiation on a plant pathogen through its effect on the host's physiology.

Plans. Research will continue on the screening of new and promising post-harvest decay inhibitors, washing techniques and research on source of inoculum. The biphenyl treatment for decay control will receive emphasis in relation to time, temperature and air movement.

Publications: Fungicidal Screening Tests for the Control of Decay in Florida Oranges. G. A. Meckstroth, J. R. Winston and C. F. Melvin. AMS-352, Dec. 1959.

Promising Decay Inhibitors. J. J. Smoot, G. A. Meckstroth and C. F. Melvin. Plant Disease Reporter 44, No. 6, pp. 383-386. June 1960.

C. Product Protection During Marketing

8. MAINTAINING QUALITY DURING TRANSIT

MQ

Problem: Current research is needed to determine fruit quality as affected by the faster rail and truck schedules, new mechanical refrigerated equipment, heavy loads, different containers and packages, loading patterns and the channeling of air. The shipment of hydrocooled citrus fruit presents additional problems in the protection of fruit quality.

Program: A continuing program of shipping tests conducted in cooperation with Florida, California and the Hawaii Experiment Stations, growers, shippers, carriers and receivers at Honolulu, Hawaii; Orlando, Florida; Pomona, California; Harlingen, Texas; New York, New York; and Chicago, Illinois, and involving about three professional Federal man-years annually.

Progress: Rail shipping tests from California to New York. Rail test results showed that fruit cooling began as soon as Cargotemp cars were loaded. Fans were powered by diesel engines. The operation of the fans was controlled by thermostats and fruit temperatures of 45° F. were reached in 24 hours. Carlots loaded by the space bonded block methods, cooled better than the conventional chimney load.

Truck Shipments. No experimental work was done this year. A report being written to cover the work up to this time will include the following suggestions for handling citrus, especially warm oranges in truck trailers:

- (a) Fan output should be kept high. About 2,500 c.f.m. would seem to be an ideal air-movement for warm orange loads. Very little cooling was accomplished at rates below 1,000 c.f.m.
- (b) The calibration of the thermostats must be checked frequently.
- (c) Relocating the sensing element of the recorder from a side wall position to the supply air stream would give the driver a better check on condenser and thermostat operation.
- (d) The lengthwise channel load with a baffle above the load to prevent short circuiting of air gave superior results provided air movement was good and the refrigeration unit was operating at maximum capacity. Better cooling was accomplished by providing 15 to 20 small channels lengthwise of the load, than by fewer large area channels.

Combination transit test (piggyback). Work on this project was continued to include tests of the sea-land service, introduced in Texas in November 1959. The mechanically-refrigerated trailers are hauled over the highway from loading point to Houston, Texas, where they are stowed aboard ship for transport to Port Newark, New Jersey. An incentive rate applies to the 36,000 to 42,000 pound load with no extra charge for refrigeration. In order to get these heavy loads into the trailer, solid loading patterns are used. The lack of air channels through the loads result in slow and uneven cooling. A winter test shipment of grapefruit in 80-pound master cartons, with total weight in excess of 40,000 pounds, arrived in acceptable condition. The average load temperature, based on five test locations, was reduced from 70° F. to 40° during the 6-day transit period with the thermostat set at 34°. The range in temperatures, at destination was from 28° (with some ice crystals in fruit) in the top layer to 45° F. in the bottom layer near the doorway. A similar type test load shipped later, with higher outside air temperatures, arrived with considerable green mold decay. The average load temperature was reduced during transit from 69° to 50° F. with a range in temperatures from 36° to 62° at destination.

The results of test shipments with both truck-rail and sea-land services indicate that a realistic evaluation of the refrigeration requirement of the particular commodity involved should be the primary factor in determining load size.

Papayas from Hawaii. The objective of this cooperative project with the Hawaii Agricultural Experiment Station is to determine the effects of different sterilization methods and transit temperatures on subsequent keeping quality of papayas.

During the past year 4 lots of papayas were received from Hawaii. Two of these had been sterilized with vapor heat and the other two with ethylene dibromide. One lot of each treatment was shipped in vans aboard ship and the other stowed in the usual way. Loading temperatures of the fruit were from 80° to 87° F. and transit temperatures 45° to 50° F. after a cooling period of 2 to 3 days. Total time in transit was 8 to 13 days.

Decay on arrival was negligible. However, after 6 days at approximately 76° F., about 20 percent of the heat-treated fruit and 62 percent of the ethylene dibromide treated fruit was overripe or decayed.

Export California citrus. This work was to determine the effectiveness of biphenyl treatment and carton venting in improving the condition of California lemons on European markets. Three test shipments were made to Hamburg, West Germany during the summer of 1959. Fruit was packed in vented and nonvented cartons, one-half of each being treated with a commercial application of biphenyl; the remaining half received no biphenyl. At the end of the transit period and 2 weeks holding without refrigeration at the Hamburg harbor (to simulate the time required for the fruit to reach the consumer), average decay of lemons in cartons without biphenyl was 14.6 percent in nonvented cartons and 7.6 percent in vented ones. Biphenyl reduced decay to 4.2 percent in nonvented cartons and 4.9 percent in vented ones. Soilage from Penicillium spores in cartons without biphenyl was 43.5 percent in nonvented cartons and 17.3 percent in vented ones. Biphenyl reduced soilage to 3.3 percent in nonvented cartons and 6.2 percent in vented ones.

The results strongly favored the use of biphenyl. Nonvented cartons were slightly better than vented ones when biphenyl was used but the difference was not statistically significant. Vented cartons were far superior to nonvented ones when biphenyl was not used.

Improvements in rail tests. Accompanied citrus (lemons and oranges) transportation tests were made from California to New York in August 1959 and January 1960 at the request of the California citrus industry to determine ice requirements and temperatures attained by fruit during transit under the faster rail schedules and newer rail equipment now available. In the warm weather test with 8 cars of oranges and 6 cars of lemons, the lowest average fruit temperatures in the cars of oranges were maintained in the shipper precooled loads. The next lowest was in the carrier precooled loads. All of these resulted in lower average fruit temperatures than any of the regular icing services without pre-cooling. Average fruit temperature was lower in ventilated cartons of

lemons than in nonventilated ones. The largest difference was 10 degrees between loads of the 2 carton types with the same icing services.

Two full bunker reicings in transit gave about the same results as half stage standard refrigeration.

Two of the winter cars, billed vents open to Ogden, arrived with slightly higher temperatures than iced cars. The other two cars, however, equaled ice refrigeration services and reached 45° F. average fruit temperature in 70 hours. Little cooling was accomplished until cold outside weather was encountered in the vicinity of Donner Pass 36 to 40 hours after loading.

Plans: Rail and truck transit studies of citrus and subtropical fruits will be continued on hydrocooling, heavy loads, loading patterns and comparison of containers in connection with fungicidal treatments. Studies on maintaining quality of California fresh citrus in truck shipments have been completed and no further shipping tests are planned for truck-rail (piggyback) service. Plans are indefinite on the shipping tests of papayas from Hawaii because of the destruction of port facilities for papaya shipments by the recent tidal wave. No further overseas tests are planned for the immediate future.

Publications: Shipping Florida Citrus Fruit in Wirebound Crates and Cartons - A Comparison of Commercial Practices. J. R. Winston, R. H. Cubbedge, J. Kaufman, USDA AMS: 342. October 1959.

9. PROTECTION OF DRIED CITRUS PULP AGAINST INSECT INFESTATION MQ

Problem: Effective methods are needed for controlling and preventing insect infestation of dried citrus pulp animal feed in storage. Because animal feed is considered a processed food, the treatments developed must leave no residues which will be objectionable according to the requirements of the Food Additive Amendment to the Food, Drug and Cosmetic Act.

Program: This is one phase of a continuing long-range program of basic and applied research on the development of control and preventive measures for insects attacking stored processed foods and is conducted at Savannah, Georgia in cooperation with industry. It involves two professional Federal man-years annually.

Progress: Synergized pyrethrum surface treatments were found to be less effective this past season than in the previous two years for preventing and controlling moth infestations in dried citrus pulp animal feed in Florida. The field observations were confirmed by laboratory tests which showed that larvae of the Florida warehouse

strain were markedly less susceptible to pyrethrum-piperonyl butoxide spray and residue than were those of the strain which had no prior exposure to the insecticide.

Field tests evaluating malathion as a surface stack treatment for protecting stored dried citrus pulp were completed. The results showed that an initial application of malathion at the rate of 150 mg. per square foot to the surface of stacked feed in burlap bags, followed by monthly applications of 75 mg. per square foot of the active ingredient, will render excellent protection against both moth and beetle infestation. The malathion treatment was not only much more effective than the synergized pyrethrum commonly used but the cost was only about one-third that for the pyrethrum.

Because a residue of malathion was obtained in the feed within the surface bags, the American Cyanamid Company conducted toxicological tests to determine whether the presence of malathion in animal feed was objectionable. Feeding malathion at more than ten times the maximum obtained with the malathion surface stack treatment caused no trace of the insecticide in the milk. The tissue analyses have not yet been completed. The company plans to petition the Food and Drug Administration for a tolerance on malathion in dried citrus pulp if the tissue analyses are favorable.

Plans: Tests are in progress to determine the effectiveness of the pathogen Bacillus thuringiensis for controlling moth infestation in stored citrus pulp and will be continued. No other work is planned because of lack of funds.

D. Transportation, Storage and Packaging

10. IMPROVED LOADING METHODS FOR CITRUS, AVOCADOS AND LIMES

Problem: Increasing freight, protective service, and labor costs, mounting losses from spoilage, damage and reduced shelf life because of ineffective refrigeration and ventilation during transportation have resulted in substantial losses to shippers, receivers, and carriers and greatly increased marketing costs for many agricultural products in recent years.

Program: This is a continuing study involving test shipments by rail and truck of various commodities in bulk and in different types of containers from various producing areas throughout the country to different terminal markets to develop and test new loading patterns, load securing equipment, measurement of container and product damage, air velocity, temperature differentials, and labor requirements for loading and unloading. It is carried out from Washington, D. C. and Orlando, Florida, with the informal cooperation

of shippers, receivers, railroads, truck lines, container and loading equipment manufacturers, State experiment stations and other interested groups. In the past year test shipments utilizing new load patterns were carried out for limes and avocados and work begun on developing improved loading methods for truck shipments of oranges and grapefruit packed in fiberboard boxes. The work involves about 2 professional Federal man-years annually.

Progress: Avocados and Limes. A study of the problems of disarranged loads, damaged containers and bruised and overheated fruit in truck shipments of these products from Florida resulting from inadequate and haphazard loading methods was made on 25 commercial shipments about two years ago. This research led to an AMS recommendation to the Florida Avocado and Lime Administrative Committees that the outside dimensions of the containers of various sizes used for these fruits be revised in such a way that they would fit into a modular unit of common outside dimensions to facilitate better loading and stacking. By the 1959-60 shipping season enough progress had been made in this direction to enable the designing and testing of an improved loading pattern which provided for circulation of refrigerated air over, around, and through the entire length of the load for more effective refrigeration of the fruit. Shipping tests with the new pattern have shown no load disarrangement or container damage, much better refrigeration of the fruit with no overheating or over-ripening in transit. In contrast control shipments with conventional loading patterns had considerable load disarrangement, blocked ventilation channels, with the fruit in one part of the load chilled, and that in another part of the load overheated. The principal cooperating shipper in this research has since adopted the new loading pattern and has reported the almost complete elimination of fruit overheating and load disarrangement in all his shipments.

Oranges and Grapefruit. Research was begun on the development of improved loading methods for truck shipments of oranges and grapefruit packed in fiberboard boxes. A new loading pattern which permits air circulation over, around, and through the load for improved refrigeration has been developed and given preliminary tests. Shipping tests with the new "air-flow" pattern in shipments made under ventilation and refrigeration showed substantially greater cooling rates than the conventional tightly stacked loads. The new pattern provides for 21 longitudinal air channels throughout the entire length of the load yielding increased air circulation and heat removal. It helps to guard against container damage because of its greater stability. The new pattern can be used by shippers and truckers with little or no increase in cost and no sacrifice in the quantity of fruit shipped as compared to the conventional load. A publication is in press on "Improved Loading Methods for Florida Avocados and Limes".

Plans: The research with avocado and lime shipments has been completed and no further work is planned. Additional shipping tests with the new loading patterns for corrugated fiberboard boxes of oranges and grapefruit will be made during the coming year. This research will also be expanded to include the development of new loading patterns for wirebound citrus containers.

Publications. Air-Flow Loading Pattern for Truck Shipments of Fresh Citrus. Russell H. Hinds, Jr., USDA, Agricultural Marketing, October 1960.

11. DEVELOPMENT OF PALLET CONTAINERS FOR TRANSPORTATION OF ORANGES AND GRAPEFRUIT

TF,FS

Problem: With an increasing number and quantity of fruits and vegetables being prepackaged at the terminal market level, to which points they are usually shipped in conventional shipping containers, they are, in effect, packaged twice. Use of pallet containers with capacities of from 500 to 2,200 lbs. and which can be filled, dumped and handled automatically can reduce container, packing and handling costs and may produce savings in freight and protective service costs. A need for pallet containers may also exist for shipment of citrus fruit to juicing and processing plants located at considerable distances from the producing areas.

Program: This long term economic-engineering program covers the development of pallet containers for the transportation of various commodities. It involves container design, laboratory and shipping tests, and analysis of commodity damage and comparative costs. The work is conducted from Washington, D. C. and Orlando, Florida in cooperation with the Forest Products Laboratory, container manufacturers, shippers, receiver-prepackagers, and transportation agencies. It involves about 3 Federal professional man-years annually.

Progress: The development of different designs of pallet containers suitable for transportation of oranges, grapefruit, and other commodities has been under way for about 2 years. During the past year 4 shipping tests were made with expendable and semi-expendable pallet containers in shipments of Florida oranges and grapefruit by truck and sea-land trailers to northern market and prepackaging plants. Pallet containers of both wirebound and corrugated fiberboard construction have been studied. Several designs have interchangeable parts, and with the substitution of body panels of different height, they can be easily and quickly converted for other commodities

which can stand more overhead weight. Shipping tests by truck from Florida to Minnesota have shown that fruit bruising and condition to be about the same for pallet container shipments as for shipments in smaller conventional containers. Time studies have shown considerable savings in labor requirements for loading, unloading, dumping, and related handling. Progress was also made in the development and testing of special equipment, materials and methods to facilitate more efficient use of these large containers.

Eight designs of bins proposed by a private firm under contract to the Agricultural Marketing Service were reviewed in the Forest Products Laboratory. Based on the review, recommendations were made as to needed changes to facilitate service test. Of the designs reviewed, two were commercial fiberboard, three were wirebound, and one a Forest Product Laboratory designed fiberboard bin on a wood pallet base. In a 30-minute vibration test, all designs bulged somewhat; however, the Forest Products Laboratory designed bin bulged the least. In addition, three box pallets were fabricated (double-wall tray and cap, and inner and outer double-wall tubes with 1- by 4-inch posts at the center of each side). These box pallets were sent to Florida for use in test shipments of citrus to Minneapolis, Minnesota.

Plans: Additional shipping tests with Florida oranges and grapefruit to northern markets in pallet containers of various designs are planned for the 1960-61 shipping season. New designs of containers and methods and equipment for more efficient handling of the containers will be studied.

E. Equipment, Facilities, Methods and Firm Efficiency

12. Improved Methods, Equipment, Plant Layout and Design for Handling and Packing Citrus Fruit

TF, ME

Problem: Growers and packinghouse operators need more efficient methods, devices, and equipment, and improved designs for packinghouse facilities for handling, precooling, degreening, and preparation for market of fresh citrus fruits at shipping points to minimize labor and related costs and maintain fruit quality.

Program: This continuing long-range program of engineering and economic research is carried on by field offices located at Gainesville, Florida and Athens, Georgia in cooperation with the

Florida Agricultural Experiment Station, the Agricultural Research Service and commercial packers, utilizing about three professional Federal man-years annually.

Progress: Handling. Tests were conducted under commercial conditions involving the handling of fresh citrus fruits in six different types of pallet boxes, all the way from the picker to the packing line. Preliminary results from the first season's work show that: (1) Efficient applications can be worked out for handling fruit in the grove; (2) degreening can be done satisfactorily; (3) fruit injury can be kept within a favorable range in relation to that for other established handling systems; (4) efficient commercial applications can be developed at the packinghouse; (5) labor requirements for handling at the packinghouse can be significantly reduced; and (6) costs for the pallet box system are significantly below those for handling fruit in the convenient 90 lb. field box.

Degreening. Studies of the degreening of fruit in pallet boxes were conducted in connection with the handling studies. Tests also were made of the degreening behavior of citrus fruit in a miniature pallet box having solid sides and bottom made of plywood. Inside dimensions of the miniature box were 24" x 24" x 28" deep, about the same depth as the pallet boxes tested under commercial conditions. These tests indicate that fruit can be degreened in a box having completely solid sides and bottom, but not as satisfactorily as in a box having ventilation openings. It also was found that a significantly higher percentage of the smaller size fruit in a given lot was satisfactorily degreened than was true of the larger sizes in the same lot. These results indicate the possibility of savings in degreening time by sizing fruit before it is degreened.

Precooling. Values of the effective thermal diffusivity and conductivity have been satisfactorily determined for oranges of the Hamlin, Parson Brown, and Valencia varieties. This information will be useful to designers and operators of precooling systems in determining the cooling rates of oranges of various sizes and at various cooling media temperatures. Laboratory tests were initiated to determine the thermal conductivity of the separate components of citrus fruit. This work has not progressed beyond the stage of developing the test procedure and calibrating the apparatus and instrumentation used.

Studies of the thermal history of citrus fruit during precooling, in three types of coolers, were carried out. These were: (1) Two stage hydrocooler designed for pallet boxes; (2) one stage hydrocooler for fruit in bulk; and (3) air cooling room. Data from the studies have not been analyzed.

Preparation of Fruit for Market. Additional data were obtained on sizing equipment to supplement those obtained last season. The transverse, drop-roll sizer, first used during the 1958-59 season in one packinghouse, was again studied and modified (by the manufacturer) on the basis of Departmental recommendations. A check study, after this modification was made, indicated that further modification was needed to provide satisfactory sizing of ellipsoidal-shaped fruit. The manufacturer plans further changes in accordance with recommendations based on these studies. A manuscript for an article covering the results of sizing work is about complete.

An experimental fixture for forming and assembling two-piece, telescoping cartons was made and tested. Data indicate that this fixture can increase the output of formed and assembled cartons by 30 to 40 percent.

Time study and work sampling data were obtained on automatic, count-fill machine packing of citrus in cartons ("shaker pack") for the purpose of comparing the cost of this method with that of conventional manual packing.

A design was developed for converting conventional bin-type citrus packing stations to "roll-board" stations. Earlier work covered only the design and construction of roll-board packing stations where the conventional stations were first removed; primarily for changing over to a central sizing. Roll-board packing stations were installed in two additional packinghouses during the year making a total of four Florida packinghouses now having such facilities. A manuscript covering the design and installation of the roll-board stations for manual packing of citrus was completed.

Plans were developed for modifying the sizer in the University of Florida campus packinghouse to make possible studies of the effect of different belt-and-roll speeds on the sizing performance of the belt-and-roll type sizer.

Plans: Experimental work on pallet box handling of fresh citrus fruit from the picker to the packing line will be continued. As

further results from this work becomes available, they will be projected into new facility designs, layouts, and equipment types for the purpose of obtaining maximum benefits from this handling and degreening system. A preliminary report on costs based on one year's operation will be issued.

Sizing studies will be continued to develop data on equipment design features affecting sizing accuracy.

Work will be continued on developing an engineering-economic analysis of "shaker pack" methods and recommendations for the application of this method to packinghouse conditions.

A laboratory test will be undertaken to determine air movement patterns inside filled pallet boxes as affected by shape, location, and area of ventilation openings in the boxes. Laboratory tests will be continued to determine the influence of size of fruit on degreening time.

An engineering-economic analysis will be made of two-stage citrus packing (fruit held temporarily after sizing and later packed to order) to compare it with the conventional packing procedures where fruit of each size is packed into shipping containers as it leaves the sizer. One new packinghouse, incorporating two-stage packing, went into operation last season.

Further improvements in the roll-board method of manual packing will be appraised as they are brought to light through experience with this method. The development of improved methods for manually filling small bags from a roll-board packing station will be undertaken. Work will be continued on the development of the carton-forming fixture.

Laboratory studies to determine the effective thermal diffusivity of whole specimens and the thermal conductivity of separate components of grapefruit and additional varieties of oranges will be continued. Correlations between the results of the two studies will be made to determine why differences exist in the thermal properties of different varieties.

An air-cooling test chamber will be designed and installed at the Citrus Experiment Station, Lake Alfred, Florida, and tests will be initiated this fall to determine the cooling rates of oranges at varying rates of airflow and varying air temperatures.

Publications: Converting Conventional Citrus Packing Stations to Roll-Board Packing Stations. G. E. Yost. Citrus Magazine. May 1960.

F. Costs, Margins, and Organization of the Marketing System

13. MARKETING CALIFORNIA DATES

ME

Problem: Date growers and packers need information on the relative costs of different methods of performing specific packinghouse operations to assist them in adopting methods which will lower costs. Information also is needed on industry organization and prospects to assist them in adjusting to changing market conditions.

Program: A survey of 33 date packinghouses was made to determine present costs of packing. Detailed economic-engineering studies were made, under contract with the Midwest Research Institute, Kansas City, Missouri, in 6 of the more modern plants to determine the most efficient methods of packing dates. One professional man-year annually was required.

Progress: Important factors affecting costs of date packinghouse operation are size of the packinghouse, hours operated per season, types of equipment and methods of operation, efficiency of labor, quality of dates received, and the quality and grades of dates packaged. Mechanization of date packing operations has made relatively slow progress because of the limited size of most packinghouses and the relatively short season of operation. The largest plants have mechanized much more than smaller plants, but have achieved only relatively small reductions in costs. Better control of overhead and supervisory costs in the smaller plants permits them to operate at a unit cost not much higher than those of the large plants.

Grading requires the largest expenditure for labor of any operation, methods being generally similar in all packinghouses. Workers in the largest packinghouses graded approximately one-third more dates per day than those in medium-sized packinghouses, apparently because of better control of fruit movement along the grading belt, wider spacing of graders on the belt, and better employee training.

A report has been made available to interested date packinghouses on costs and efficiency in the operation, which will enable them to compare their own costs with those of the rest of the industry and to take steps to reduce costs.

Plans: Project completed. No further work planned.

Publications: Marketing Domestic Dates: Packinghouse Practices and Costs. By Dale G. Stallings, USDA Marketing Research Report No. 373, November 1959.

14. COMPETITION IN THE MARKETING OF GRAPEFRUIT

ME

Problem: The grapefruit industry needs to know the competitive relationships between Florida, Texas, and California grapefruit in terms of price relationships and the effect on grower incomes of varying quantities of grapefruit from the production areas.

Program: This phase of the long-range study of citrus marketing has been conducted at Gainesville, Florida, as a contributing study to the Southern Regional Citrus Marketing Project, "The Economic Efficiency of Marketing Florida, Texas, and Puerto Rico Citrus Fruit." It involves 1 man-year annually of Federal professional personnel.

Progress: An analysis of price relationships has been undertaken. Preliminary investigations indicate that there are price relationships between varietal types that can possibly be explained by supplies and other variables. On the basis of analysis of prices for one market (Chicago) it appears that during the pre-freeze period, prices of similar varieties of grapefruit from Texas and Florida were about equal, but there was a consistent differential of \$.50 to \$1.00 for the various Texas colored varieties over Florida white seedless.

Plans: A more refined analysis of price relationships will be made. Theoretical least-cost distribution of grapefruit will be determined for various volume levels in producing areas to determine the probable effect of future volume changes on grower incomes.

15. CHANGES IN METHODS OF MARKETING

ME

Problem: Citrus industry leaders need more accurate information on the changes taking place in wholesale markets for fruits and vegetables to evaluate the impacts of these changes on the citrus industry and to assist in making decisions and recommendations for adjustments to meet these changes.

Program: A 3- to 4-year research program involving about four professional Federal man-years annually, in cooperation with the Agricultural Experiment Stations in Wisconsin, West Virginia, Kentucky, Maine, Montana, Nebraska, New York, Utah, New Mexico, Louisiana, Arkansas, South Carolina, Oklahoma, and Minnesota, and through contract studies in the San Francisco market area by the University of California, Berkeley, California, and in the Pittsburg market by Midwest Research Institute, Kansas City, Missouri.

Progress: From the study on Chainstore Merchandising and Procurement Products it was found that direct buying by corporate and voluntary chainstores has increased markedly in the postwar years as many more chains grew to a size which made it attractive to them. It can be expected to continue to increase as other corporate and voluntary chains grow to this size. This will mean an increased demand for more.

uniform products. The size of the lot purchased by individual organizations will increase, on the average. It will be increasingly difficult to dispose of variable lots, small lots, and lots of odd size, grade, color, etc. This may mean increasing emphasis on large packing and shipping operations which can put up uniform lots which will meet the specifications of some part of the chainstore market. Markets may tend to become more segmented, as more direct buyers line up a small number of shippers with whom they deal regularly. Volume control will become more important, as the market for supplies which cannot be sold to direct buyers shrinks, and the effect of each additional carload added to or withdrawn from this market will become more pronounced. Wide swings in supply may cause wider swings in price than formerly and it will be more difficult to clean up supplies in a market because the number of buyers will have declined.

Fieldwork has been completed for a study of the present status and organization of 52 wholesale fruit and vegetable markets throughout the country. This information will provide the basis for description of the structure of wholesale markets and an analysis of the role of terminal markets in the years ahead.

Plans: This work will be substantially completed during the coming year with completion of the analysis and publication of the findings.

Publications: Chainstore Merchandising and Procurement Practices. The Changing Retail Market for Fresh Fruits and Vegetables. William E. Folz and Alden C. Manchester, USDA Marketing Research Report No. 417, July 1960.

16. IMPROVED PRICING METHODS

FCS

Problem: Improved pricing plans and grower payment methods are needed to more accurately reflect changing market requirements back to growers and grower organizations so as to better balance supplies with demand. Changing industry organization and procurement practices required by mass distribution are bringing about more complex product specifications, and have altered pricing techniques which reduce the effectiveness of conventional pricing methods.

Program: This continuing long-range program of applied research, part of which is contributing to the Western Regional Project WM-38, is conducted in major production areas and involves about one professional Federal man-years annually.

Progress: Current work in this area involves (a) a comparison of returns to growers of selected fruits and vegetables from various grower payment methods, and (b) an analysis of the impact of bargaining associations on the market structure and behavior of the fruit and

vegetable processing industry. Neither phase has progressed to a stage where findings can be reported.

Again at the request of growers, a Fourth National Conference on Fruit and Vegetable Bargaining Cooperatives was held in January 1960 at Atlanta, and proceedings prepared and distributed.

Plans: Work will be continued and publications are planned on both phases of this study.

Publications: Co-op Grower Payment Methods in a Changing Market. C. B. Markeson. News for Farmer Cooperatives, February 1960.

Proceedings of the Fourth National Conference on Fruit and Vegetable Bargaining Cooperatives. FCS Unnumbered Report. January 1960.

Some Facts About Fruit and Vegetable Bargaining Cooperatives. W. M. McMillan., FCS Information 11. December 1959.

17. IMPROVING COORDINATION AND DISTRIBUTION METHODS

FCS

Problem: Changing marketing conditions require improved methods for the coordination and distribution of fruit to meet the needs of large-scale buyers, as well as to improve the competitive position of growers in a mass-distribution system. Basic economic information is needed to assist in making marketing decisions which will reduce costs, increase sales, maximize returns and meet the needs of the market.

Program: This continuing long-range program of applied research is conducted in major producing areas and is contributing to Southern Regional Citrus Marketing Project SM-22. It involves about two professional Federal man-years annually.

Progress: Building on work which analyzed returns and sales practices of Florida fresh citrus marketing organization, the project now nearing completion provides information on the need and feasibility for a joint marketing program. All fresh citrus shippers handling in excess of 100,000 boxes of fruit annually were contacted in this survey. Of 120 shippers interviewed 84, or 70 percent saw a need for more joint sales activity. Of those shippers not already associated with a coordinated sales organization 47 percent expressed a willingness to participate in some kind of joint activity. Major marketing problems reported by shippers were related to changes affecting market outlets which resulted in fewer buyers and in specification buying practices, particularly of fruit sizes.

Work was continued on the final aspects of a report dealing with possibilities of an improved marketing program for Florida avocados and limes. Results of the analysis of the distribution of these two commodities were discussed at a meeting attended by representatives

of growers, shippers, and the Florida Agricultural Extension Service. Major shippers were interviewed to learn recent changes due to the 1957 freeze, and to continuing encroachment of suburban housing developments. Publication of the report will complete the avocado and lime phase of this area of work.

Plans: Immediate plans are to complete the final report on need and feasibility for developing a joint marketing program for Florida fresh citrus fruit.

Plans are being developed to follow this work with a study of direct marketing problems at shipping point with particular reference to their importance for a joint sales operation. Direct sales are accounting for an increasingly large share of the volume of Florida citrus fruit and other fresh fruit and vegetable shipments. Their effect on shippers' supply situations, shifts in direct buying practices, specification order problems and industry growth generally will be examined with emphasis on ultimate returns to growers.

Publications: A Joint Marketing Program for Florida Fresh Citrus Fruit. Fred E. Hulse, FCS Service Report 50, (Preliminary Report), December 1959.

18. DEMAND, OUTLOOK AND SITUATION ANALYSES FOR CITRUS AND SUBTROPICAL FRUITS

Problem: Producers, processors, distributors, and consumers need information on past and future production and consumption of citrus and subtropical fruit and the effect of these and other factors on price.

Program: Continuing statistical analysis of data and preparation of periodic situation and outlook reports, supplemented from time to time with special statistical studies of factors that affect demand and price, using data assembled by census and agricultural estimates, and other agencies, carried on in Washington, D. C., and involving one Federal professional man-year annually.

Progress: Situation and outlook work has continued with regularly scheduled reports of The Fruit Situation, The Demand and Price Situation, and The National Food Situation. A special article in The Fruit Situation, June 1960, showed that per capita consumption of citrus fruit, fresh plus processed on a fresh equivalent basis, trended upward over the past two decades. The increase was mostly in oranges, which comprised about two-thirds of total consumption of citrus in recent years. Since 1947, per capita consumption of frozen orange juice has increased sharply, more than offsetting decreases in canned orange and grapefruit juice. A feature special to The Fruit Situation, August 1960, was a set of 7 tables presenting historical series on

per capita consumption of individual and broad groups of fresh and processed fruits and tree nuts.

Some work for an economic analysis of the demand for lemons and lemon products has been done but the study has not progressed to the findings stage. Methods that might be used in analyzing the competitive demands for fresh fruit and processed products have been considered. Some of these relationships may be difficult to measure because of the extensive shifts that have taken place in lemon marketing during a relatively short period.

Some exploratory research on demand for fresh oranges, grapefruit and processed products was done to determine the feasibility of expanding research in this area. Work on citrus is coordinated with the regional research.

Plans: Continue regular analyses and the issuance of situation reports, complete the analysis of the demand for lemons and lemon products, and expand work on demand for oranges and grapefruit and processed products.

Publications: The Fruit Situation is published four times a year, with a comprehensive outlook report in the October issue.

The Demand and Price Situation is published monthly and includes a summary of the price situation for fruit.

The National Food Situation is published quarterly and includes a summary of supply and consumption of fruit.

Trends in the Consumption of Citrus Fruits, Ben H. Pubols, Fruit Situation, (TFS-135), June 1960.

19. FOREIGN COMPETITION AND MARKET ANALYSES STUDIES ON CITRUS AND AVOCADOS FAS

Problem: The development of foreign markets for fresh fruit and processed products through the study of export markets and evaluation of foreign fruit industries competing with the United States.

Program: This continuing long-range project involves first-hand studies of European markets and foreign competing areas. Recent developments in producing and market areas are analyzed, and reported. One professional Federal employee devotes full time to this program, spending about three months of each year in foreign areas. His observations are reported to the industry in department publications and through industry visits.

Progress: Activities in 1959 included a survey of the citrus industry of Italy and nine European markets. In 1960 an analysis was made of the citrus industry of Spain and two European markets. Findings indicate that expanding Mediterranean and Southern Hemisphere industries will result in more competition for U. S. citrus. Prosperous Europe will use more oranges and grapefruit as prices are lower, and trends in tastes and merchandising methods will increase the market opportunities for citrus products.

Factual information on production and trade are made available on a regular schedule. Circulars on the competitive outlook are published for the winter season in late December or January, and for the summer season in April or May. These outlooks contain the actual production and exports of competing countries for four past seasons, together with an estimate of production and exports for the current season. The winter outlook includes U. S. exports to the world for the winter and summer season of oranges, lemons, and grapefruit. U. S. trade on citrus products is also reported at this time.

Reports are made on European marketing conditions as information is available and surveys made. In the fall of 1959, circulars were published which included information on 12 European markets. One of these, "U. S. Markets for Processed Citrus," outlined Europe's trade by source and months as the information was available. The other publication, "Western Europe -- A Market for Fresh Citrus," included data on European imports by month and source. In addition, every other year the Fruit and Vegetable Division bulletin, "Information Relating to World Production and Trade in Fresh and Processed Citrus" is brought up-to-date. Surveys are made of competitive producing areas and the findings published in Foreign Agricultural Reports.

In September 1959, a citrus specialist attended the Catania, Sicily Congress of Mediterranean citrus producers as an observer, and in May 1960 a U. S. delegation participated in the first meeting of the FAO citrus study group in Madrid, Spain.

Plans: Surveys will be made of the citrus industries of Greece and Mexico, and European markets in 1960-61. Reports will be prepared on the citrus industries of Italy and Spain.

In May 1961 a U. S. delegation will participate in the second FAO citrus study group at Rome, Italy.

A circular on the avocado industries of Brazil, Madeira, Israel, Southern Africa, and European avocado markets is in preparation.

Publications: Circulars (USDA, FAS)

Western Europe: A Market for U. S. Citrus Products. J. H. Burke.
FCF 4. August 1959.

Western Europe: A Market for U. S. Fresh Citrus. J. H. Burke.
FCF 5. September 1959

U. S. Winter Citrus: Outlook for Competition in Europe. J. H.
Burke. FCF 1. January 1960.

"CLAM" Spells Keener Competition from Mediterranean Citrus. J. H.
Burke, FCF 2. April 1960.

U. S. Summer Citrus: Outlook for Competition in Europe. J. H.
Burke. FCF 3. July 1960.

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